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RESEARCH INSTITUTE, NEW DELHI

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An administrative grouping made effective in 1985, including activities of the following Departments:

Department of Embryology

Organized in 1914; Franklin P. Mall, Director 1914-1917

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CARL G. HARTMAN
CHESTER H. HEUSER

MARGARET R. LEWIS
WARREN H. LEWIS
CHARLES W. METZ

Department of Genetics

Station for Experimental Evolution, opened in 1904, was combined with Eugenics Record Office in 1921 to form Department of Genetics. Charles B. Davenport, Director 1904-1984.

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M. DEMEREC, *Assistant Director*
H. H. LAUGHLIN, *Assistant Director*
AMOS G. AVERY
R. W. BATES
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OSCAR RIDDLE
SOPHIA SATINA
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MORRIS STEGGERDA
H. E. WARMKE

Nutrition Laboratory

Organized in 1907, opened in 1908; F. G. Benedict, Director 1907-1987

T. M. CARPENTER, *Acting Director*
V. COROPATCHINSKY

ROBERT C. LEE

Tortugas Laboratory

Established in 1904. Alfred G. Mayor, Director 1904-1922; W. H. Longley, Executive Officer 1924-1987

D. H. TENNENT, *Executive Officer*

P. S. CONGER, *Assistant*

HISTORICAL RESEARCH

DIVISION OF HISTORICAL RESEARCH

A. V. KIDDER, *Chairman*

Department of Historical Research was organized in 1908; Andrew C. McLaughlin, Director 1908-1905, J. Franklin Jameson, Director 1905-1928. In 1980 this Department was incorporated as the Section of United States History in a new Division of Historical Research.

Section of Aboriginal American History

SYLVANUS G. MORLEY
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ALFONSO CASO, Archaeology
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RESEARCH ASSOCIATES ENGAGED IN POST-RETIREMENT STUDIES

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SOPHIE D. ABERLE (United States Office of Indian Affairs), Anthropology
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ORGANIZATION, PLAN, AND SCOPE

The Carnegie Institution of Washington was founded by Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him on January 19, 1911. Furthermore, the income of a reserve fund of about three million dollars, accumulated in accordance with the founder's specifications in 1911, is now available for general use and a sum of five million dollars has been paid by the Carnegie Corporation of New York as an increase to the Endowment Fund of the Institution, payments having been completed in 1931. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of the *Carnegie Institution of Washington*. (See existing Articles of Incorporation on following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, and the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind."

The Institution is essentially an operating organization. It attempts to advance fundamental research in fields not normally covered by the activities of other agencies, and to concentrate its attention upon specific problems, with the idea of shifting attack from time to time to meet the more pressing needs of research as they develop with increase of knowledge. Some of these problems require the collaboration of several investigators, special equipment, and continuous effort. Many close relations exist among activities of the Institution, and a type of organization representing investigations in astronomy, in terrestrial sciences, in biological sciences, and in historical research has been effected. Conference groups on various subjects have played a part in bringing new vision and new methods to bear upon many problems. Constant efforts are made to facilitate interpretation and application of results of research activities of the Institution, and an Office of Publications provides means for appropriate publication.

ARTICLES OF INCORPORATION

PUBLIC No. 260. An Act to incorporate the Carnegie Institution of Washington

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings, and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, *Samuel P. Langley*, William Lindsay, Seth Lowe, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, *Ethan A. Hitchcock*, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occa-

ARTICLES OF INCORPORATION

sioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold, and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature;

CARNEGIE INSTITUTION OF WASHINGTON

and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books, or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904

BY-LAWS OF THE INSTITUTION

Adopted December 13, 1904. Amended December 13, 1910, December 13, 1912,
December 10, 1937, and December 15, 1939

ARTICLE I

THE TRUSTEES

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

ARTICLE II

MEETINGS

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

ARTICLE III

OFFICERS OF THE BOARD

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

CARNEGIE INSTITUTION OF WASHINGTON

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties.

ARTICLE IV

EXECUTIVE ADMINISTRATION

The President

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall sign and execute on behalf of the corporation all contracts and instruments necessary in authorized administrative and research matters and affix the corporate seal thereto when necessary, and may delegate the performance of such acts and other administrative duties in his absence to the Executive Officer. He may execute all other contracts, deeds, and instruments on behalf of the corporation and affix the seal thereto when expressly authorized by the Board of Trustees or Executive Committee. He may, within the limits of his own authorization, delegate to the Executive Officer authority to act as custodian of and affix the corporate seal. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

4. There shall be an officer designated Executive Officer who shall be appointed by and hold office at the pleasure of the President, subject to the approval of the Executive Committee. His duties shall be to assist and act for the President as the latter may duly authorize and direct.

5. The President shall retire from office at the end of the calendar year in which he becomes sixty-five years of age.

BY-LAWS OF THE INSTITUTION

ARTICLE V

COMMITTEES

1. There shall be the following standing Committees, *viz.* an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of five members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall have power to authorize the purchase, sale, exchange, or transfer of securities and to delegate this power. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request

CARNEGIE INSTITUTION OF WASHINGTON

of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

ARTICLE VI

FINANCIAL ADMINISTRATION

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees, or as provided in Article V, paragraph 6, hereof.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures of the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

ARTICLE VII

AMENDMENT OF BY-LAWS

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

ABSTRACT OF MINUTES OF THE FORTY-FIRST MEETING OF THE BOARD OF TRUSTEES

The meeting was held in Washington in the Board Room of the Administration Building on Friday, December 15, 1939. It was called to order by the Chairman, Mr. Forbes.

Upon roll call, the following Trustees responded: Thomas Barbour, James F. Bell, Robert Woods Bliss, Frederic A. Delano, Homer L. Ferguson, W. Cameron Forbes, Walter S. Gifford, Walter A. Jessup, Frank B. Jewett, Charles A. Lindbergh, Roswell Miller, Stewart Paton, Elihu Root, Jr., Henry R. Shepley, William Benson Storey, Richard P. Strong, Charles P. Taft, James W. Wadsworth, and Lewis H. Weed. The President of the Institution, Dr. Vannevar Bush, was also in attendance.

The minutes of the fortieth meeting were approved as printed and submitted to the members of the Board.

Reports of the President, the Executive Committee, the Auditor, the Finance Committee, the Auditing Committee, and of Chairmen of Divisions, Directors of Departments, and Research Associates of the Institution were presented and considered.

The following appropriations for the year 1940 were authorized:

Pension Fund	\$60,000
Administration	110,300
Publications (including Office of Publications)	73,440
Departments and Divisions of Research	1,017,652
Minor Grants	55,100

\$1,316,492

Mr. Forbes was re-elected Chairman of the Board, Mr. Gifford was re-elected Vice-Chairman, and Mr. Delano was re-elected Secretary, each for the ensuing period of three years.

Robert Woods Bliss, Walter A. Jessup, and Lewis H. Weed were re-elected members of the Executive Committee for a period of three years.

Walter S. Gifford, Alfred L. Loomis, Henry S. Morgan, Elihu Root, Jr., and Frederic C. Walcott were re-elected members of the Finance Committee for a period of three years, with Mr. Walcott as Chairman. Frederic A. Delano was re-elected Chairman of the Auditing Committee for a period of three years, and Robert Woods Bliss and James W. Wadsworth were elected as the other members of the Auditing Committee for the same period.

Upon recommendation of the Executive Committee, the Articles of the By-Laws of the Institution were amended to read as follows:

ARTICLE III

OFFICERS OF THE BOARD

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties.

CARNEGIE INSTITUTION OF WASHINGTON

ARTICLE IV

EXECUTIVE ADMINISTRATION

The President

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall sign and execute on behalf of the corporation all contracts and instruments necessary in authorized administrative and research matters and affix the corporate seal thereto when necessary, and may delegate the performance of such acts and other administrative duties in his absence to the Executive Officer. He may execute all other contracts, deeds, and instruments on behalf of the corporation and affix the seal thereto when expressly authorized by the Board of Trustees or Executive Committee. He may, within the limits of his own authorization, delegate to the Executive Officer authority to act as custodian of and affix the corporate seal. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

4. There shall be an officer designated Executive Officer who shall be appointed by and hold office at the pleasure of the President, subject to the approval of the Executive Committee. His duties shall be to assist and act for the President as the latter may duly authorize and direct.

5. The President shall retire from office at the end of the calendar year in which he becomes sixty-five years of age.

ARTICLE V

COMMITTEES

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall have power to authorize the purchase, sale, exchange, or transfer of securities and to delegate this power. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

ARTICLE VI

FINANCIAL ADMINISTRATION

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees, or as provided in Article V, paragraph 6, hereof.

In accordance with action of the Board of Trustees at its meeting of December 9, 1938, the Chairman appointed Standing Committees of the Board for the year as follows:

Committee on Astronomy: Herbert Hoover, *Chairman*; Walter S. Gifford, Roswell Miller, Elihu Root, Jr., and William Benson Storey.

Committee on Terrestrial Sciences: Frank B. Jewett, *Chairman*; Frederic A. Delano, Homer L. Ferguson, Henry S. Morgan, and James W. Wadsworth.

Committee on Biological Sciences: Lewis H. Weed, *Chairman*; Thomas Barbour, James F. Bell, Alfred L. Loomis, and Stewart Paton.

Committee on Historical Research: Henry R. Shepley, *Chairman*; Robert Woods Bliss, Charles A. Lindbergh, Richard P. Strong, and Charles P. Taft.

The meeting adjourned at 11:55 A.M.

REPORT OF THE EXECUTIVE COMMITTEE

FOR THE YEAR ENDING OCTOBER 31, 1939

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the fiscal year ending October 31, 1939.

During this year the Executive Committee held seven meetings, printed reports of which have been mailed to each Trustee.

A full statement of the work of the Institution is contained in the report of the President, which has been considered and approved by the Executive Committee, and is submitted herewith. A detailed estimate of expenditures for the succeeding year is also contained in the report of the President, and has been considered by the Executive Committee, which has approved the recommendations of the President in respect thereto and has provisionally approved the budget estimates based thereon and submitted therewith. Close attention has been given both by the Executive Committee and by the Finance Committee to the question of availability of funds for Institution activities in 1940, and budget recommendations are based upon judgment of these Committees with respect to financial policy in the face of declining income and the problem of investment of funds.

Upon recommendation of the Finance Committee, and in accordance with terms of enabling resolutions authorized by the Board of Trustees at its meeting of December 13, 1935, the Executive Committee has approved a revised plan for operation of a Cooperative Investment Office, located in New York City, to provide service to the following organizations: Carnegie Foundation for the Advancement of Teaching; Teachers Insurance and Annuity Association of America; Carnegie Endowment for International Peace; Carnegie Institution of Washington. This Office was set up on July 1, 1939, with appointment of Devereux C. Josephs as Senior Investment Officer, and Parker Monroe as Junior Investment Officer.

Standing Committees of the Board were appointed by the Chairman at the annual meeting on December 9, 1938, in accordance with action taken by the Board at that time. Members of the Committees have on several occasions advised with the President in formulation of recommendations for future conduct of work of the Institution. By reason of appointment of these Committees, the President reports that he has been greatly benefited through direct contact with individual members of the Board and with groups of Trustees.

The Board of Trustees, at its meeting of December 9, 1938, appointed Arthur Young and Company to audit the accounts of the Institution for the fiscal year ending October 31, 1939. The report of the Auditor, including a balance sheet showing assets and liabilities of the Institution on October 31, 1939, is submitted as a part of the report of the Executive Committee.

In addition to the report of the Auditor there is also submitted a financial statement for the fiscal year ending October 31, 1939, showing funds available for expenditure and amounts allotted by the Executive Committee, and a customary statement of receipts and disbursements since the organization of the Institution on January 28, 1902. These statements together with the tables in the Auditor's report comprise a full statement of the finances of the Institution.

No vacancies exist in the membership of the Board of Trustees. Tenures of office of the following officers of the Board of Trustees will expire at the annual meeting on December 15: Mr. Forbes, Chairman of the Board; Mr. Gifford, Vice-Chairman of the Board; and Mr. Delano, Secretary of the Board. Tenures of office of Messrs. Bliss, Jessup, and Weed as members of the Executive Committee, of Messrs. Gifford, Loomis, Morgan, Root, and Walcott as members of the Finance Committee, and of Messrs. Delano, Ferguson, and Storey as members of the Auditing Committee also expire at the meeting of December 15.

W. CAMERON FORBES, *Chairman*
ROBERT WOODS BLISS
VANNEVAR BUSH
FREDERIC A. DELANO
WALTER S. GIFFORD
WALTER A. JESSUP
FREDERIC C. WALCOTT
LEWIS H. WEED

November 3, 1939

FINANCIAL STATEMENT FOR FISCAL YEAR ENDING OCTOBER 31, 1939

	Balances unallotted Oct. 31, 1938	Trustees' appropriation Dec. 9, 1938	Reversions and transfers Nov. 1, 1938, to Oct. 31, 1939	Total available 1939	Executive Committee allotments 1939	Transfer by Executive Committee	Unallotted balances Oct. 31, 1939
Large Grants:							
Animal Biology							
Administrative Expenses		\$2,300		\$2,300.00	\$2,300.00		
Embryology		78,842	\$500.00	79,342.00	79,342.00		
Genetics		143,220	1,500.00	144,720.00	144,720.00		
Nutrition Laboratory	\$320.00	26,000		26,320.00	26,000.00	\$320.00	
Tortugas Laboratory		12,000		12,000.00	12,000.00		
Geophysical Laboratory		162,934	3,500.00	166,434.00	166,434.00		
Historical Research		146,900		146,900.00	146,900.00		
Mount Wilson Observatory		220,380	1,100.00	221,480.00	221,480.00		
Plant Biology		99,835	500.00	100,335.00	100,335.00		
Terrestrial Magnetism		190,800	5,320.00	196,120.00	196,120.00		
Minor Grants	9,866.01	124,000	20,927.76	154,793.77	151,350.00		\$3,443.77
Publications	61,220.62	67,640	16,817.98	145,678.60	110,837.54		34,841.06
Administration		104,440		104,440.00	104,440.00		
Pension Fund		60,000		60,000.00	60,000.00		
General Contingent Fund	67,513.83	60,000	44,495.10	172,008.93	42,289.62	66,320.00	63,399.31
Special Emergency Reserve Fund		20,000		20,000.00	20,000.00		
	\$138,920.46	\$1,519,291	\$94,660.84	\$1,752,872.30	\$1,584,548.16	\$66,640.00	\$101,684.14

AGGREGATE CASH RECEIPTS AND DISBURSEMENTS FROM ORGANIZATION, JANUARY 28, 1902, TO OCTOBER 31, 1939

RECEIPTS		DISBURSEMENTS	
<i>Securities Sold or Redeemed</i>	\$64,742,405.09	<i>Securities Purchased</i>	\$72,613,251.17
<i>Interest from Securities and Bank Balances</i>	45,453,598.28	<i>Accrued Interest on Securities, Purchased</i>	658,598.69
<i>Sales of Publications</i>	341,930.31	<i>Pension Fund</i>	1,009,417.40
<i>Colburn Estate (Bequest)</i>	52,015.74	<i>Insurance Fund</i>	129,020.89
<i>Tepple Estate (Bequest)</i>	5,100.62	<i>Special Emergency Reserve Fund</i>	63,772.95
<i>Carnegie Corporation of N. Y. (Endowment Increase and for Specific Purposes)</i>	7,641,381.24	<i>General Contingent Fund</i>	223,529.06
<i>From Other Organizations and Individuals for Specified Purposes</i>	374,470.50	<i>Administration Building and Addition:</i>	
<i>Pension Fund (Refunds)</i>	82,134.60	Construction and Site (Old Building).....	309,915.69
<i>Insurance Fund (Refunds)</i>	12,733.51	Construction (Addition to Administration Bldg.)..	416,206.07
<i>Adm. Bldg. Addition Account, Rentals and Refunds</i> ..	18,021.09	Site (Addition to Administration Building).....	68,570.96
<i>Miscellaneous Refunds and Receipts</i>	477,578.94	Miscellaneous Expenditures*.....	39,836.55
		<i>Large Grants:</i>	
		Departments of Research, Buildings and Equipment	3,698,707.86
		Departmental Operations.....	27,689,390.11
		<i>Minor Grants</i>	5,191,404.87
		<i>Publication</i>	2,671,902.26
		<i>Administration</i>	2,208,117.35
		<i>National Research Council</i>	150,000.00
		<i>Miscellaneous</i>	9,008.82
		<i>October 31, 1939, Cash in Banks</i>	\$117,150,650.70
			2,050,719.22
			\$119,210,369.92

* Includes Equipment \$7,208.41, Repairs and Alterations to Old Building \$18,999.29.

REPORT OF AUDITORS

*To the Board of Trustees
Carnegie Institution of Washington
Washington, D. C.*

We have made an examination of the books and accounts of CARNEGIE INSTITUTION OF WASHINGTON for the year ended October 31, 1939.

Income from investments and other sources has been duly accounted for and all disbursements were evidenced by paid voucher checks and/or properly approved invoices. The cash and securities were verified by certificates received from depositories and custodians. As in past years, the detail accounts of the Departments of Research in the field have been audited by the Bursar of the Institution and we are of the opinion, as a result of reviewing the internal audit methods in force, that such internal audit is satisfactorily conducted.

The securities are stated at cost or value at date acquired, this being the established custom of the Institution. Real estate and equipment are stated at original cost and books on hand for sale at their sales prices.

We inspected certified copies of the minutes of the meetings of the Board of Trustees and Executive Committee as authority for the appropriations and allotments made during the year.

In our opinion, on the basis of valuations stated above, the accompanying balance sheet, statement of receipts and disbursements and detailed schedule of securities properly present the financial position of the Carnegie Institution of Washington at October 31, 1939 and the transactions for the year ended that date.

ARTHUR YOUNG & COMPANY
Accountants and Auditors

*New York, N. Y.
November 30, 1939*

BALANCE SHEET, OCTOBER 31, 1939

Assets		LIABILITIES	
<i>Investments</i>		<i>Endowment and Other Funds</i>	
<i>Securities</i>		<i>Capital Funds</i>	
Cash	\$33,541,982.15	Endowment	\$30,377,030.49
Awaiting investment	1,709,402.70	Colburn Fund	3,214,919.57
Reserved for current needs	42,546.73	Reserve Fund	
		Harriman Fund (\$183,671.75 included in Property Fund below)	304,188.73
		Teagle Fund	5,100.62
			\$34,014,634.74
<i>Property Account</i>		<i>Special Funds</i>	
Real Estate and Equipment		Insurance Fund	698,664.94
at original cost		Pension Fund	351,092.45
Office of Administration	836,434.19	Special Emergency Reserve Fund	268,582.70
Departments of Research	3,698,707.86	Special Reserve Fund for Administration Bldg. Addition	988.82
		Current Funds, Invested	160,000.00
			35,493,963.65
		Loss from redemption and sale of Securities (Awaiting yearly apportionment)	
			200,052.07
			\$35,293,911.58
<i>General Fund</i>		<i>Property Fund</i>	
Cash	\$298,769.79	Income Invested	
Income account	500.00	Harriman Property (Gift)	4,351,470.30
Petty cash and stamps			183,671.76
Income uncollected for the year 1939		<i>General Fund</i>	
		Current Obligations	274,731.76
		Large Grants	68,689.28
		Minor Grants	86,240.97
		Publications	27,822.10
		Administration	77,748.11
		General Contingent Fund	
		Unappropriated Fund	535,232.22
			10,888.75
		Less Current Funds, Invested (See above)	546,120.97
			386,120.97
Books on hand at sale price	261,166.10	Value of Publications and Invoices	
Outstanding accounts on sales of publications	807.99	Publication Paper Stock	261,974.09
Paper in stock for future publications	3,690.77		3,690.77
			651,785.83
			\$40,480,839.46

CASH RECEIPTS AND DISBURSEMENTS FOR THE YEAR ENDED OCTOBER 31, 1939

Receipts	Disbursements
<p>Securities Redeemed or Sold.....</p> <p>Interest and Dividends from Securities.....</p> <p>Sales of Publications.....</p> <p>Refunds.....</p> <p>From Other Organizations and Individuals for Specific Purposes:</p> <p>Carnegie Corporation of New York.....</p> <p>National Research Council.....</p> <p>California Institute of Technology.....</p> <p>International Cancer Research Foundation.....</p> <p>National Committee on Maternal Health.....</p> <p>Rockefeller Foundation.....</p> <p>Contributions.....</p> <p>Teeple Estate (Bequest).....</p> <p>Pension Fund (Refunds).....</p> <p>Insurance Fund (Refunds).....</p> <p>Administration Building Addition Account (Refunds).....</p>	<p>Securities Purchased.....</p> <p>Accrued Interest on Securities Purchased.....</p> <p>Pension Fund.....</p> <p>Insurance Fund.....</p> <p>General Contingent Fund.....</p> <p>Administration Building Addition.....</p> <p>Special Emergency Reserve Fund.....</p> <p>Departmental Operations.....</p> <p>Research Projects in Cooperating Organizations.....</p> <p>General Publication.....</p> <p>Office of Publications.....</p> <p>Administration.....</p>
<p>\$8,097,550.24</p> <p>1,536,695.03</p> <p>6,174.28</p> <p>10,337.56</p> <p>77,800.00</p> <p>4,275.00</p> <p>5,199.92</p> <p>2,750.00</p> <p>4,500.00</p> <p>4,000.00</p> <p>3,250.00</p> <p>5,100.62</p> <p>436.92</p> <p>449.64</p> <p>570.46</p>	<p>\$6,388,093.86</p> <p>11,330.16</p> <p>72,292.06</p> <p>8,555.21</p> <p>23,689.12</p> <p>101,337.65</p> <p>31.76</p> <p>*1,154,481.78</p> <p>116,955.68</p> <p>74,601.72</p> <p>26,244.27</p> <p>103,434.43</p>
<p>Cash in Banks, November 1, 1938.....</p>	<p>Cash in Banks, October 31, 1939:</p> <p>Uninvested principal:</p> <p>Awaiting investment.....</p> <p>Reserved for current needs.....</p> <p>Income account.....</p>
<p>\$9,759,089.67</p> <p>372,677.25</p>	<p>\$1,709,402.70</p> <p>42,546.73</p> <p>\$1,751,949.43</p> <p>298,769.79</p>
<p>\$10,131,766.92</p>	<p>2,050,719.22</p> <p>\$10,131,766.92</p>

* Includes specific terminating projects administered through departments.

SCHEDULE OF SECURITIES

Aggregate— par or nominal value	Description	Registered		Ma- turity	Int. due	Total cost or value at date acquired
		Princ. and int.	Princ. only			
	<i>Railways</i>					
\$240,000	A. T. & S. Fe 1st and ref. 4½s.			1962	M-S	\$239,400.00
37,000	A. T. & S. Fe conv. 4s.			1955	J-D	33,577.50
50,000	A. T. & S. Fe gen. 4s.	*		1995	A-O	50,056.25
50,000	Balto. & Ohio R. R. ref. 4s.			1941	M-N	46,875.00
100,000	Balto. & Ohio R. R. 1st Mtg. 5s.	*		1948	JAJO	105,500.00
100,000	Balto. & Ohio R. R. gen. and ref. 5s.			1995	J-D	102,516.67
50,000	Balto. & Ohio R. R. gen. and ref. 5s.			1996	M-S	30,307.50
98,000	Boston & Maine R. R. Co. 1st Mtg. 4½s.			1961	A-O	28,058.14
111,000	Boston & Maine 1st 5s.			1967	M-S	75,186.20
100,000	Canadian National Ry. Co. 5s.			1969	J-J	98,500.00
100,000	Canadian National Ry. Co. 4½s.			1957	J-D	112,000.00
91,000	Canadian Pac. Col. Trust 5s.			1954	J-D	90,835.11
100,000	Ches. & Ohio Ry. gen. 4½s.			1992	M-S	99,484.29
25,000	Ches. & Ohio Ry. Eq. Tr., Series 1929 4½s.			1940	M-N	24,161.60
50,000	Central Pac. Ry. 1st ref. 4s.	*		1949	F-A	48,250.00
47,000	Chicago B. & Q. R. R. gen. 4s.			1958	M-S	24,129.17
100,000	Chicago B. & Q. R. R. Ill. Div. 4s.	*		1949	J-J	97,750.00
189,000	Chicago Ind. & L. 1st and gen. 5s.			1966	M-N	189,461.25
35,000	Chicago M. & St. P. & P. 5s.			1975	F-A	31,853.50
140,000	Chicago M. St. P. & P. conv. adj. 5s.			2000	A-O	127,414.50
234,000	Chicago M. & St. P. Ry. gen. 4½s (\$5,000 fully reg., \$29,000 reg. princ.)	*	*	1989	J-J	227,162.50
120,000	Chicago & N. W. Ry. gen. 3½s.	*		1987	FMAN	100,300.00
200,000	Chicago & N. W. Ry. gen. 4½s.			1987	M-N	210,000.00
300,000	Chicago R. I. & P. Ry. 4½s.			1952	M-S	280,964.50
20,000	Chicago Union Station Co. 1st Mtg. 3½s.			1963	J-J	20,850.00
75,000	Chicago & W. Indiana R. R. Co. cons. 4s.			1952	J-J	70,357.66
50,000	Clev. C. & St. Louis Ry. ref. and imp. 4½s.			1977	J-J	49,636.25
50,000	Clev. C. C. & St. Louis Ry. gen. 4s.			1993	J-D	39,453.12
100,000	Elgin, Joliet & E. Ry. Co. 5s.			1941	M-N	107,125.00
300,000	Erie R. R. gen. 4s.			1906	J-J	242,937.50
90,000	Erie R. R. Eq. Trust 4½s.			1942-43	J-D	86,467.90
69,000	Great Northern Ry. 1st ref. 4½s.			1961	J-J	69,156.75
50,000	Great Northern Ry. gen. 4½s.			1977	J-J	49,062.50
100,000	Great Northern Ry. gen. 5s.			1973	J-J	104,385.84
75,000	Ill. Cent. R. R. Joint 5s.			1963	J-D	77,823.36
100,000	Ill. Cent. R. R. ref. 4s.			1955	M-N	89,966.12
120,000	Ill. Cent. Eq. Trust 4½s.			1942-44	A-O	115,184.84
200,000	Kan. City F. S. & M. Ry. ref. 4s (Certificate of Deposit)			1936	A-O	187,250.00
225,000	Lbhigh and L. E. 4½s.	*		1957	M-S	229,547.29
150,000	Louisville & N. R. R. 1st and ref. 4½s.			2003	A-O	149,475.00
100,000	Mo. Kan. & T. 1st 4s.			1990	J-D	82,603.13
213,000	Mo. Pac. R. R. Co. 1st and ref. 5s.			1977	M-S	212,762.50
150,000	Mo. Pac. R. R. Eq. Trust 4½s.			1940-42	M-N	143,961.61
150,000	Mobile and O. R. R. ref. and imp. 4½s (Certificate of Deposit)			1977	M-S	145,750.00
75,000	N. Y. Cent. R. R. ref. and imp. 4½s.			2013	A-O	37,624.87
50,000	New York Chicago & St. L. R. R. Co. ref. Mtg. 4½s.			1978	M-S	46,851.14
50,000	New York Penna. & Ohio R. R. 4½s.			1950	M-S	52,500.00
50,000	N. Y. W. and Boston 1st 4½s.	*		1946	J-J	49,187.50
100,000	Northern Pacific ref. and imp. 6s.			2047	J-J	100,300.00
50,000	Northern Pacific gen. lien 3s.	*		2047	FMAN	33,101.25
51,000	Oregon Short Line con. 5s.			1946	J-J	49,373.25
75,000	Penna. R. R. Co. gen. 4½s.			1965	J-D	75,918.75
125,000	Penna. R. R. Co. con. 4½s.			1960	F-A	130,828.13
50,000	Pere Marquette Ry. Co. 1st Mtg. 5s.			1956	J-J	44,282.50
50,000	Pitta. C. C. & St. L. 5s.			1975	A-O	51,898.98
42,000	Pitta. Shawmut & Nor. 4s (Certificate of Deposit)			1952	J-J	4,200.00
98,000	So. Pac. 1st ref. 4s.			1955	J-J	91,513.53
50,000	So. Pac. conv. 4½s.			1969	M-N	45,000.00
129,000	Southern Rwy. Co. 1st con. 5s.			1994	J-J	133,618.64
225,000	St. Louis-S. F. prior lien 4s (Certificate of Deposit)			1950	J-J	203,431.25
70,000	Term. R. R. Assn. of St. Louis gen. and ref. 4s.			1953	J-J	63,603.92
100,000	Texas & Pac. Ry. gen. and ref. 5s.			1977	A-O	101,848.82
100,000	Toledo & Ohio Central Ry. Co. ref. and imp. 3½s.			1960	J-D	99,000.00
2,084,000	Union R. R. deb. 6s.	*		1946	J-D	2,084,000.00
65,000	Union Pac. 1st lien and ref. 4s.			2008	M-S	59,829.02
150,000	Virginian Ry. Co. 1st lien and ref. 3½s.			1966	M-S	153,375.00
40,000	Wabash R. R. Co. 1st 5s.			1939	M-N	37,750.00
200,000	Wabash Ry. ref. and gen. 5s.			1976	F-A	203,250.00
100,000	West Shore R. R. Co. 1st Mtg. 4s.	*		2361	J-J	78,140.00
50,000	Western Md. R. R. 1st and ref. Mtg. 5½s.			1977	J-J	42,677.19
\$9,283,000	Railway Sub-Total.....					\$8,840,783.84

SCHEDULE OF SECURITIES—Continued

Aggregate— par or nominal value	Description	Registered		Ma- turity	Int. due	Total cost or value at date acquired
		Princ. and int.	Princ. only			
Public Utility						
\$100,000	Ala. Power Co. 1st and ref. 4½s			1967	J-D	\$87,265.00
231,000	Ala. Power Co. 1st and ref. 5s			1968	M-S	219,516.25
51,000	Am. Tel. & Tel. Co. deb. 3½s			1961	A-O	51,510.00
314,000	Am. Tel. & Tel. Co. deb. 3½s			1966	J-D	326,706.75
125,000	Am. Tel. & Tel. Co. sink. deb. 5½s			1943	M-N	130,260.62
300,000	Appalachian Electric Power Co. 1st Mtg. 4s			1963	F-A	296,250.00
300,000	Ark. P. & L. Co. 5s			1956	A-O	292,812.50
56,000	Bell Tel. Co. of Canada 1st 5s			1955	M-S	57,715.00
29,000	Birmingham Electric Co. 1st ref. 4½s			1968	M-S	27,362.10
75,000	Blackstone Valley Gas & Elec. 4s			1955	M-N	76,875.00
300,000	Carolina Power & L. Co. 1st and ref. 5s			1956	A-O	302,298.75
380,000	Columbia Gas & Elec. Corp. deb. 5s			1961	J-J	379,762.50
300,000	Columbus Rwy. P. & L. 4s			1965	M-N	304,500.00
23,900	Commonwealth Edison Co. conv. 3½s			1958	J-J	23,910.75
83,000	Commonwealth Edison Co. 1st Mtg. 3½s			1968	J-D	85,712.87
50,000	Consolidated Edison Co. of N. Y. deb. 3½s			1948	A-O	50,875.00
40,000	Consolidated Edison Co. of N. Y. deb. 3½s			1958	J-J	40,730.00
100,000	Detroit Edison gen. and ref. 4s			1965	A-O	103,500.00
325,000	Georgia Power Co. 1st ref. 5s			1967	M-S	320,112.50
200,000	Gulf States Util. Co. 1st Mtg. and ref. 3½s			1969	M-N	213,500.00
25,000	Houston Ltg. & Power Co. 1st Mtg. 3½s			1966	J-D	25,750.00
200,000	Illinois P. & L. 1st and ref. 5s			1956	J-D	196,750.00
173,000	Indianapolis P. & L. 1st 3½s			1968	F-A	173,000.00
213,000	Inter. Tel. & Tel. deb. 4½s			1952	J-J	204,657.50
280,000	Interborough Rap. Trans. ref. 5s (Certificate of Deposit)			1966	J-J	277,164.75
25,000	Lone Star Gas Corp. deb. 3½s			1953	F-A	26,406.25
150,000	Louisiana Power & Light Co., 1st 5s			1957	J-D	154,900.00
100,000	Metropolitan Edison Co. 1st 4½s			1968	M-S	109,470.00
100,000	Minnesota P. & L. 1st and ref. 4½s			1978	M-N	92,156.25
50,000	Monongahela West Penn. Pub. Serv. Co. 1st and gen. 4½s			1960	A-O	52,000.00
100,000	Montana Power Co. 1st and ref. 3½s			1966	J-D	101,000.00
25,000	Mountain States Tel. & Tel. Co. deb. 3½s			1968	J-D	25,500.00
52,000	New Eng. Tel. & Tel. 5s			1952	J-D	51,748.00
100,000	New Orleans Pub. S. 5s			1955	J-D	99,200.00
65,000	New York & Westchester Ltg. 5s			1954	J-J	67,052.50
300,000	New York P. & L. 1st 4½s			1967	A-O	286,125.00
47,000	North American Co. deb. 3½s			1949	F-A	47,822.50
18,000	North American Co. deb. 3½s			1954	F-A	18,180.00
10,000	North American Co. deb. 4s			1959	F-A	10,125.00
150,000	Northern Ind. Pub. S. 1st ref. 5s			1966	M-N	152,887.50
50,000	Northern States Power Co. 1st and ref. 3½s			1967	F-A	47,500.00
100,000	Ohio Edison Co. 1st Mtg. 4s			1967	M-S	100,266.25
100,000	Ohio Power Co. 1st 3½s			1968	A-O	101,500.00
100,000	Ohio Public Serv. Co. 1st Mtg. 4s			1962	F-A	102,625.00
200,000	Okl. G. & E. 1st 3½s			1966	J-D	205,000.00
100,000	Pac. G. & E. Co. 1st and ref. 3½s			1961	J-D	102,500.00
100,000	Pac. G. & E. Co. 1st and ref. 4s			1964	J-D	104,000.00
200,000	Penn. Electric Co. 1st and ref. 5s			1962	A-O	203,882.50
104,000	Penn. Water & Power Co. 1st ref. 4½s			1968	M-S	101,619.94
136,000	Pub. Serv. Co., of Indiana 1st and ref. 6s			1952	F-A	112,540.00
141,000	Pub. Serv. Co., of No. Ill. 1st Mtg. 3½s			1968	A-O	145,230.00
60,000	Puget Sound Power & L. 1st and ref. 4½s			1950	J-D	56,550.00
50,000	Puget Sound Power & L. 1st and ref. 5½s			1940	J-D	31,900.00
250,000	Shawinigan Water & Power Co. 1st and coll. 4½s			1967	A-O	238,510.42
75,000	Southern Bell Tel. & Tel. Co. deb. 3½s			1962	A-O	72,375.00
200,000	Southern Calif. Edison Co. 1st and ref. 3½s			1960	J-J	197,000.00
300,000	Texas Electric Service 5s			1960	J-J	292,700.00
200,000	Texas Power & Light Co. 1st and ref. 5s			1956	M-N	205,143.75
120,000	Toledo Edison 1st Mtg. 3½s			1968	J-J	121,800.00
250,000	Union Elec. Co. of Missouri 1st Coll. Trust 3½s			1962	J-J	249,537.50
220,000	Utah L. & T. Co. ref. 5s			1944	A-O	215,193.00
263,000	Virginia Elec. & Power Co. 1st and ref. 3½s			1968	M-S	272,205.00
225,000	Wisconsin Electric Power Co. 1st 3½s			1968	A-O	232,875.00
\$9,109,900	Public Utility Sub-Total					\$9,075,024.20
State and Municipal						
\$50,000	City of Cleveland, Water Works, 5½s			1967	M-N	\$52,984.60
25,000	City of Detroit, Water Supply, 4s			1955	J-D	24,812.50
25,000	City of Detroit, Water Supply, 4½s			1952	M-S	25,250.00
50,000	City of Newark, Street Opening, 5½s			1958	F-A	51,724.94
50,000	City of New York, 4½s			1957	M-N	58,531.25
84,000	State of North Carolina, Highway, 4½s (\$30,000 registered)					
50,000	City and County of San Francisco, Hetch Hetchy, 5½s	*		1953-63	J-J	92,819.50
				1960	J-D	53,523.34
\$334,000	State and Municipal Sub-Total					\$359,646.13

SCHEDULE OF SECURITIES—Continued

Aggregate— par or nominal value	Description	Registered		Ma- turity	Int. due	Total cost or value at date acquired
		Princ. and int.	Princ. only			
<i>Mortgages</i>						
\$25,000.00	Empire Title and Guarantee Co. Guaranteed 1st Mtg., Ctf. No. 1676, 5% .....	*	.....	1939	FMAN	\$25,000.00
99,750.00	Lawyers Mtg. Co. Guaranteed 1st Mtg. Ctf., Series 18397, 4% .....	*	.....	1944	J-J	99,750.00
80,000.00	Lawyers Title and Guaranty Co., 5½% Mtg. ....	*	.....	1935	A-O	80,000.00
96,524.35	Lawyers Title and Guaranty Co. Guaranteed 1st Mtg. 5% .....	*	.....	1942	J-J	96,041.73
100,000.00	Lawyers Mtg. Co. Guaranteed 1st Mtg. 4% .....	*	.....	1940	MJSD	100,000.00
90,000.00	N. Y. Title and Mtg. Co. Guaranteed 1st Mtg. Ctf., 5½% .....	*	.....	1938	J-D	90,000.00
98,000.00	N. Y. Title and Mtg. Co. Guaranteed 1st Mtg. 4½% .....	*	.....	1940	J-D	98,000.00
90,000.00	Participation Ctf. in Consol. Bond and Mtg., SE. Cor. Madison Ave. and 40th St., Man- hattan, 4% .....	*	.....	1944	J-D	90,000.00
\$679,274.35	Mortgages Sub-Total					\$678,791.73
<i>Industrial</i>						
\$50,000	Allis-Chalmers Mfg. Co. conv. deb. 4s			1952	M-S	\$51,587.00
50,000	American Radiator Co. deb. 4½s			1947	M-N	49,125.00
50,000	Atlantic Refining Co. deb. 3s			1953	M-S	51,187.50
150,000	Bethlehem Steel Corp. conv. deb. 3½s			1952	A-O	148,760.00
97,000	Bethlehem Steel Corp. cons. sink. fund 4½s			1960	J-J	95,545.00
49,000	Loew's Incorporated deb. 3½s			1946	F-A	48,728.58
8,000	Phelps Dodge Corp. conv. deb. 3½s			1952	J-D	6,000.00
140,000	Railway Express Agency 1½-2½s			1942-48	J-D	140,000.00
100,000	Remington Rand Inc. deb. 4½s			1956	M-S	100,162.50
94,000	Scovill Manufacturing Co. conv. deb. 5½s			1945	J-J	96,747.66
200,000	Shell Union Oil Corp. deb. 2½s			1954	J-J	192,945.00
75,000	Socony Vacuum Oil Co. deb. 3s			1964	J-J	78,000.00
53,000	Southern Kraft Corp. 1st leasehold and gen. Mtg. 4½s			1946	J-D	51,790.00
100,000	Standard Oil Co. of N. J. deb. 2½s			1953	J-J	99,000.00
1,925,000	Tenn. C. I. & R. Co. 5s (Payment guaranteed by U. S. Steel Corp.)			1951	J-J	1,925,000.00
100,000	Texas Corp. deb. 3½s			1951	J-D	100,000.00
100,000	United States Steel Corp. deb. 3½s			1948	J-D	100,000.00
85,000	Wheeling Steel Corp. 1st Mtg. 4½s			1966	F-A	86,275.00
100,000	Youngstown S. & Tube 1st Mtg. sink. 4s			1961	M-N	98,500.00
\$3,524,000	Industrial Sub-Total					\$3,519,343.24
<i>Foreign</i>						
\$55,000	Canada, Dom. of, 5s			1952	M-N	\$60,450.00
105,500	German External Loan of 1924 7s			1949	A-O	112,713.00
71,000	Kingdom of Denmark ext. 4½s			1962	A-O	64,935.45
14,000	New South Wales ext. 5s			1958	A-O	13,269.38
100,000	Province of Alberta deb. 4½s			1958	J-J	93,750.00
100,000	Province of Alberta 5s			1950	A-O	101,150.00
150,000	Province of Manitoba deb. 4½s			1958	A-O	142,886.77
100,000	Province of Nova Scotia 4½s			1952	M-S	100,312.50
100,000	Province of Ontario 4s			1964	M-N	87,150.10
40,000	Province of Ontario 6s			1943	M-S	43,137.50
100,000	City of Toronto con. deb. 5s			1949	J-D	99,164.59
90,000	City of Toronto 5s			1952	J-D	89,333.53
\$1,025,500	Foreign Sub-Total					\$1,005,252.82
\$23,955,674.35	BONDS—Funds Invested					\$23,478,841.96
<i>Preferred Stocks</i>						
Shares	American Cyanamid Co.					\$1,230.00
120	A. T. & S. Fe pref. stock					52,125.00
500	Caterpillar Tractor Co. cum. pref.					9,772.00
67	Cons. Edison Co. cum. pref. stock					198,725.00
2,000	Du Pont de Nemours cum. pref.					116,125.00
1,125	J. I. Case Thresh. M. Co. pref. stock					82,225.00
500	Grant Co. (W. T.)					7,642.76
225	Northern States Power Co. cum. pref.					103,000.00
1,000	Union Pac. R. R. pref. stock					33,415.00
400	U. S. Steel Corp. pref. stock					715,173.50
5,000	Preferred Stocks Sub-Total					\$1,296,433.26
10,937	Preferred Stocks Sub-Total					\$1,296,433.26

SCHEDULE OF SECURITIES—Continued

Number of shares	Description	Total cost or value at date acquired
<i>Common Stocks</i>		
2,600	Air Reduction Co.....	\$155,863.00
1,000	Allied Chemical & Dye Corp.....	167,468.00
1,113	Allis-Chalmers Manufacturing Co.....	55,667.50
1,200	Alpha Portland Cement Co.....	33,250.00
1,330	American Brake Shoe & Foundry Co.....	61,891.00
1,400	American Can Co.....	128,260.00
4,000	American Cyanamid Co.....	108,410.00
5,500	American Radiator & Standard Sanitary Corp.....	100,533.00
500	American Telephone & Telegraph Co.....	83,220.00
200	American Tobacco Co.....	15,840.00
200	American Tobacco Co. "B".....	16,342.00
1,500	Bethlehem Steel Corp.....	117,325.00
2,000	Borg Warner Corp.....	78,955.77
2,300	Caterpillar Tractor Co.....	162,360.00
1,600	Chase National Bank of N. Y.....	51,800.00
1,800	Chrysler Corp.....	175,862.50
2,000	Commercial Credit Co.....	96,345.00
2,500	Commercial Investment Trust Corp.....	147,824.00
100	Commercial National Bank & Trust Co. of N. Y.....	17,880.00
400	Consolidated Edison Co. of N. Y.....	18,335.00
2,500	Continental Can Co.....	110,730.00
1,608	Continental Insurance Co.....	57,185.30
3,900	Continental Oil Corp.....	120,110.00
3,500	Deere & Co.....	69,662.50
1,400	Dow Chemical Co.....	108,298.00
1,700	E. I. Du Pont de Nemours & Co.....	259,857.50
1,500	Eastman Kodak Co.....	238,952.75
35	First National Bank of N. Y.....	80,925.00
7,200	General Electric Co.....	235,052.50
1,200	General Foods Corp.....	51,665.50
5,000	General Motors Corp.....	264,054.50
2,400	Grant Co. (W. T.).....	79,551.24
400	Guaranty Trust Co. of N. Y.....	104,414.00
4,600	Gulf Oil Corp.....	174,443.00
700	Hartford Fire Insurance Co.....	52,184.68
4,500	Hudson Bay Mining & Smelting Co., Ltd.....	148,495.00
2,700	Humble Oil & Refining Co.....	161,823.50
900	Ingersoll-Rand Co.....	96,960.00
820	Inland Steel Co.....	82,930.00
1,000	Insurance Co. of North America.....	64,962.75
746	International Business Machines Corp.....	116,998.00
2,000	International Harvester Co.....	164,952.50
3,700	International Nickel Co.....	199,217.00
1,113	Johns-Manville Corp.....	106,691.00
3,400	Kennecott Copper Corp.....	146,532.50
300	Liggett & Myers Tobacco Co. "B".....	29,516.00
1,700	Monsanto Chemical Co.....	164,854.50
3,500	Montgomery Ward & Co.....	188,430.58
400	Mortbion Corp. of N. Y.....	
3,800	National Lead Co.....	87,741.00
1,700	Newberry Co. (J. J.).....	81,864.00
2,600	New Jersey Zinc Co.....	172,294.50
2,000	Owens-Illinois Glass Co.....	135,962.50
600	Parke, Davis & Co.....	27,102.00
1,500	Penney Co. (J. C.).....	145,363.50
4,300	Phelps Dodge Corp.....	160,704.00
1,100	Pittsburgh Plate Glass Co.....	123,829.25
1,800	Procter & Gamble Co.....	100,795.82
1,100	Pullman, Inc.....	52,645.00
2,100	St. Joseph Lead Co.....	95,386.50
2,200	Sears Roebuck & Co.....	177,721.40
1,000	Sherwin-Williams Co.....	103,197.47
8,000	Socony Vacuum Oil Co.....	95,645.00
3,100	Standard Oil Co. of Calif.....	109,343.00
3,800.33	Standard Oil Co. of N. J.....	204,763.80
3,500	Texas Corp.....	151,078.26
1,600	Timken Roller Bearing Co.....	81,334.00
120	Travelers Insurance Co.....	59,433.11
1,400	Underwood Elliott Fisher Co.....	96,400.50
2,400	Union Carbide & Carbon Co.....	207,194.50
1,500	United Fruit Co.....	109,972.00
1,200	United States Gypsum Co.....	120,301.00
900	United States Steel Corp.....	92,360.00
1,800	Westinghouse Electric & Mfg. Co.....	189,877.50
2,400	Woolworth Co. (F. W.).....	112,635.00
1,520	Youngstown Sheet & Tube Co.....	108,879.75
156,705.33	Common Stocks Sub-Total.....	\$8,766,686.93
167,642.33	COMMON AND PREFERRED STOCKS—Funds Invested.....	\$10,063,120.19
	AGGREGATE INVESTMENTS (BONDS AND STOCKS).....	\$33,541,962.15

REAL ESTATE AND EQUIPMENT, ORIGINAL COST

Administration (October 31, 1939)

Washington, D. C.

Building, site, and equipment.....		\$836,434.19
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Division of Plant Biology (September 30, 1939)

Stanford University, California (Headquarters)

Buildings and grounds.....	\$149,492.61	
Laboratory	55,505.49	
Library	30,836.12	
Operating appliances	25,744.41	261,578.63

Department of Embryology (September 30, 1939)

Wolfe and Madison Streets, Baltimore, Maryland

Library	3,706.52	
Laboratory	15,410.17	
Administration	7,428.47	26,545.16

Department of Genetics (September 30, 1939)

Cold Spring Harbor, Long Island, New York

Buildings, grounds, field.....	292,749.72	
Operating	32,223.26	
Laboratory apparatus	32,354.04	
Library	48,642.85	
Archives	45,488.90	451,458.77

Geophysical Laboratory (September 30, 1939)

2801 Upton Street, Washington, D. C.

Building, library, operating appliances.....	228,718.36	
Laboratory apparatus	164,936.09	
Shop equipment	19,978.10	413,632.55

Division of Historical Research (September 30, 1939)

Administration Building, Washington, D. C.

Operating	28,448.28	
Library	9,174.28	37,622.56

Tortugas Laboratory (September 30, 1939)

Tortugas, Florida

Vessels	30,930.43	
Buildings, docks, furniture, and library.....	12,930.86	
Apparatus and instruments.....	9,322.55	53,183.84

Department of Meridian Astrometry (September 30, 1939)

Dudley Observatory, Albany, New York

Apparatus and instruments.....	4,846.84	
Operating	5,273.68	10,120.52

Nutrition Laboratory (September 30, 1939)

29 Vila Street, Boston, Massachusetts

Building, office, shop, and library.....	134,128.16	
Laboratory apparatus	37,225.12	171,353.28

Mount Wilson Observatory (September 30, 1939)

Pasadena, California

Buildings, grounds, road, and telephone line.....	222,458.33	
Shop equipment	46,225.35	
Instruments	678,432.80	
Furniture and operating appliances.....	141,679.33	
Hooker 100-inch reflector.....	630,127.44	1,718,923.25

Department of Terrestrial Magnetism (September 30, 1939)

5241 Broad Branch Road, Washington, D. C.

Building, site, and office.....	232,298.72	
Survey equipment	96,163.61	
Instruments, laboratory, and shop equipment.....	225,826.97	554,289.30

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

FOR THE YEAR ENDING OCTOBER 31, 1939

REPORT OF THE PRESIDENT
OF THE
CARNEGIE INSTITUTION OF WASHINGTON

In accordance with Article IV, section 2, of the By-Laws of the Carnegie Institution of Washington, the President has the honor to submit the following report on work of the Institution for the year ending October 31, 1939.

The position of the Institution in American science has inevitably altered in the thirty-seven years which have elapsed since it was founded. The great growth of scientific research in that period, involving the notable expansion of research facilities and staffs in educational institutions of high rank, and the advent of great commercial laboratories paying attention to fundamental matters of science as well as to applications, has substantially altered the field in which it operates. Moreover, knowledge of science itself has expanded both in breadth and in depth, bringing about increased specialization on the part of many individuals, and at the same time powerful influences of many disciplines upon others. Yet the underlying philosophy which guided the wise establishment of the Institution still applies.

The Institution has great geographical spread and wide scope in its investigations. Yet it cannot encompass all aspects of scientific effort, nor affect intimately every important center of research activity in the country. It consists primarily of a number of groups of scientific workers, supplemented by cooperating scientists in other institutions. Each group is supplied with the facilities peculiar to its own field, and is established in close proximity to centers of parallel effort. Almost without exception this

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desirable relationship has been well established and has operated successfully. The important point is that these groups are united in an operating organization of national scope, thus forming a unique network capable of usefully interlinking the efforts of individual scientists and the advances made on divergent fronts.

This great concept is of even greater significance today than when it took form in the keen minds of those who molded the Institution in its early days. For full effectiveness we need merely to recognize the changes which time has brought about, and adapt our efforts accordingly. There are now whole branches of science which we hardly touch, and which without undue scattering of effort we can hardly enter into in any comprehensive way; yet we most certainly should not fail to maintain cognizance of their progress, and be on the alert for beneficial relationship with them.

The opportunity for scientific research is unbounded. Were the Institution now just starting on its way, and had it now the much enlarged endowment which would be required if its endeavors were to be in the same ratio to the whole scientific effort as when it began, its influence could indeed be comprehensive. Nevertheless the days when it could pioneer are not ended, and it may again occasionally provide the catalyst which will invigorate important new reactions in scientific endeavor. With careful selection of those areas in which its operations may be most highly beneficial, it may still contemplate extension of its scope, at the same time carefully guarding against scattering of effort. It is an independent scientific institution of national scope, performing an essential function by interrelation and integration throughout this nation, and its prime efforts should be devoted

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to maintaining its traditional scope of operations sound and progressive, with such deliberate and well-considered shift of emphasis as general trends may indicate.

It is imperative, however, that in thus considering the broad sweep of scientific effort, in dealing with matters of organization and resources, we should not lose sight of the fact that the Institution exists mainly that individuals of great talent may be enabled to labor and create for the benefit of their fellows. It is still incumbent upon us, as it was when the founder first charged us with the responsibility, to seek out the man of genius, surround him with the tools of his technique, and provide him with the medium for expression of his thoughts. The tools of today are often vastly more complex and expensive. The growing interdependence of the sciences connotes enlarged emphasis on those facilities which have to do with cooperation and interchange. Group projects, to which men of varied backgrounds contribute diverse building blocks, may sometimes erect a complete scientific structure, when isolated effort would be futile. The painstaking coordinated effort of many workers, over years of gathering, classification, and analysis, may be necessary to provide the solid foundation on which an inspiring tower of proved theory may then reach up into the rarefied atmosphere of the unknown. Yet, in the end, all the paraphernalia of science exist, all the results are exchanged, all the calculation is carried on, in order that men of stature may think new thoughts, and render their conceptions known.

THE EMERGENCY

Much of the world is at war. We are fortunately able to stand aside, but no evaluation of the condition and pro-

gram of an institution can be completely divorced from the stress of the times in which it operates. Even in these fortunate United States all plans are thus conditioned, and every individual is thus affected.

The scientist in particular is faced with a quandary. The same science which saves life and renders it rich and full, also destroys it and renders it horrible. Is it then possible to remain in a detached atmosphere, to cultivate the slowly growing body of pure scientific knowledge, and to labor apart from the intense struggle in which the direct application of science now implies so much for good or ill? As with an individual, so with a scientific institution; we cannot consider the immediate future of the Carnegie Institution without taking cognizance of the conflict of emotions which is inevitably present.

The quandary may be immediate and direct. Science and its applications have produced the aircraft and the bomb. Entirely apart from all questions of national sympathies, from all opinion concerning political ideologies, we fear to witness the destruction of the treasures of civilization and the agony of peoples, by reason of this new weapon. As science has produced a weapon, so also can it produce in time a defense against it. Science is dedicated to the advance of knowledge for the benefit of man. Here is a sphere where the benefit might perhaps indeed be immediate, real and satisfying. Can a scientist, skilled in a field such that his efforts might readily be directed to the attainment of applications which would afford protection to his fellow men against such an overwhelming peril, now justify expending his effort for any other and more remote cause?

Every individual scientist must of course render his own answer. Only a very small percentage are in such

fields that their efforts could in any case be suddenly altered so as to become immediately effective, and these only are directly faced with the problem. Even for most of these the opportunity will be rare.

Throughout the Institution most of our work is, and should remain, far afield from the techniques of the present struggle. Yet if some of our laboratories can contribute, as they did twenty-two years ago, to the solution of immediate problems in the national interest, they should do so. In particular, if the Institution sees a way in which its activities and facilities can aid in the great problem of the protection of civilian populations from attack, it should not fail to press its efforts in that regard.

Yet we should not become stampeded. There is still a duty to keep the torch of pure science lit, and this duty is only the greater under stress. All the long struggle of a harsh evolution, the pitting of species against the environment, has produced a being whose primary distinction is conscious cerebration, and whose crowning attribute is his intellectual curiosity concerning his complex environment and a thirst for knowledge transcending the mere struggle for existence. If there is no abiding value in a Beethoven symphony, or a theory of the cosmos, or the tracing of an ancient culture, then the Carnegie Institution of Washington has scant reason for existence. If it is really good that man should look at the stars and should contemplate his great destiny, then it is imperative that in those regions which enjoy the blessings of peace the search for the eternal verities should continue.

The dual character of science influences much of our outlook. We look at the stars, and we build yet greater machines to aid our vision, for two reasons. The stars are a laboratory, wherein are pressures and temperatures far

beyond those we can artificially produce; which we can merely observe and not manipulate. Nevertheless through thus observing we have already learned many things which have advanced the science of physics and in turn its applications. All this is to be welcomed, yet it should not completely dominate our thought. We also look at the stars for the same reason that inspired the shepherd on the ancient hill, because we are bound to think of greater things than the comforts or dangers of the morrow, perhaps because thus to inquire and to speculate is the true mission of the race.

The same thread runs all through our research. We study, for one example, the complex phenomena of photosynthesis. It may be, after many years, that man will learn in detail the mechanism by which a plant thus builds food and structure from air and soil and water, by the aid of sunlight. We may even be able to duplicate the process; we may some day carry on the involved chemical transformations on raw materials exposed in trays to the sun of the desert; and this may in the next generation profoundly influence the dependence of the race upon its environment. Many laboratories now study the complex chemistry and energetics of photosynthesis with this highly practical possibility as their driving incentive. The work of the Institution has yielded in the past and may well yield in the future results which aid progress in this practical direction, and we welcome such contributions. Yet we are impelled in this research of ours by much more fundamental and deep incentives. The photochemical mechanism which produces plant life is one of the most basic of the processes that have made possible the complex evolution of life on this planet. We are a product of that evolution, and we have an underlying curiosity.

It is not an idle curiosity, unless indeed the most stirring philosophies that have moved the mind of man are all idle. Far from being futile, it is the attribute which gives man such true dignity as he succeeds in preserving in the midst of the buffeting of his hazardous existence. To unravel one of the great mysteries of life is an ambition which needs no apologies, and it is this ambition which spurs us on to try to understand the primary plant process. We need no stronger justification for our conviction of the enduring value of what we do.

Our detachment makes it possible for us to keep the even tenor of our way and largely to devote our efforts to inquiries which are the most fascinating that engage the scientific mind, and which will require long and continuous effort by many men for their solution. Some of us certainly should depart at least temporarily from this sustained effort if we see a way in which our science may definitely aid in mitigating some great immediate ill that threatens humanity. Most of us can continue along the familiar path, with clear consciences, toward a distant goal. We should be humbly grateful for the opportunity that is ours, we should be full of sympathy with those who do not share our blessings, and we should be assiduous in the preservation of the spirit of true science in a time of exceeding stress.

FINANCES

Every endowed institution feels the continuing pressure of decreasing income, and the Carnegie Institution of Washington is no exception. In the course of the past three years the annual income from endowment has decreased approximately \$300,000.

This decrease has had two effects. It has much curtailed

the extent to which new opportunities could be grasped, and to which support could be extended outside the Institution. It has forced internal retrenchments and economies. Thus far it has not seriously impaired internal operations, although it has postponed needed advances in salary, especially in the younger ranks. Needed economies have been produced largely by termination of certain efforts which were essentially auxiliary, and by minor alterations of procedure, rather than by radically restricting any of the major researches which have long been accepted as continuing activities of the Institution.

One unfortunate condition has, however, already been produced. The concept of Institution research groups, close to and in cooperative relationship with great research centers, was an early and far-reaching idea. It is especially effective when grants to those engaged in neighboring research are extensive. At present new grants of any important extent have become impossible, and continuing ones are being curtailed.

There should be a reasonable balance between our efforts through our own staff, and our support to others, since one of the primary functions of the Institution is to act as a catalyst in new fields. At present the decrease in income has produced an unbalanced situation, and the ratio between free funds available for support of individuals outside the Institution and funds devoted to regular internal operations is now undesirably low. Our own internal programs are valuable. The responsibility of the Institution to its own senior permanent scientific staff is very real. Yet the trend of events has caused us to approach a frozen condition in which the Institution would become merely one of many institutions operating a program of research. This is far from the ideal in

accordance with which the Institution, with a cementing nucleus of its own research, reaches helpfully through the entire fabric of American scientific effort, to seek out the man of unusual promise and make possible for him valuable associations and support, to initiate programs in comprehensive or untried fields, to link together many disciplines by reason of geographic spread and catholic interest.

The decrease of income now prevents us from carrying out fully the originally conceived mission for which there is no other agency in existence more fully qualified. A further decrease of available income would inevitably affect seriously our regular operations. The matter is not yet at the point of serious distress, for minor economies are still possible; but opportunity will open up largely only when the trend reverses.

Another aspect of the subject warrants attention. With war in Europe, the Institution has more than the usual responsibility to carry on in scientific fields from which many gifted individuals in other lands are now forced to retire. At the same time it is probable, as it was twenty-two years ago, that some of our laboratories will be called upon for practical efforts in the public interest in connection with the economic disruption and the emphasis on national defense. To any such call we should respond to the best of our ability; and we should do so as far as possible without impeding our fundamental research programs.

TERMINATIONS AND TAPERINGS

As scientific emphasis shifts, as programs with definite objectives are completed, more especially as individuals who have been supported in their scientific endeavors ap-

proach retirement, there should be terminations of effort to be reported to the Trustees. The present serious decrease in available income intensifies this situation, for as curtailment becomes necessary it accelerates the tapering of programs nearing completion. The staff has appreciated the situation fully, and has agreed to such steps to a surprising and reassuring extent.

The archaeological effort at Chichen Itzá at one time involved about twenty staff members in residence, and the facilities were increased accordingly. Now our excavation in Yucatan is no longer concerned with great buildings, and the Mexican Government itself is carrying out restorations on a large scale. A new contract with the Mexican Government has been entered into which contemplates that the Institution will, for the present, reduce its annual expenditure in Mexico considerably. With the full cooperation of all concerned, steps have been taken to cut down the operating plant to that needed for the new program. This involves discontinuing the attractive living arrangements at Chichen Itzá, to the sincere regret of all who have ever visited in those almost ideal surroundings. The archaeological effort, as it turns to new phases, will not, however, be hampered by the change.

The Desert Laboratory at Tucson has long been an important station of the Division of Plant Biology. It has had three main objectives: the classification and field study of the flora of the great American desert regions, the preservation of an isolated area where natural development can be observed, and laboratory investigations of the physiology of desert plants. One part of the last of these activities was abruptly interrupted by a fire on November 6, 1938, which destroyed the chemical laboratory at Tucson. Rather than restore the facilities, this

aspect of the work is now being closed out. Dr. Shreve's personal work of examination and report on desert areas will, however, continue; and it is hoped that arrangements may be made whereby the protected area may be perpetuated without undue continuing expenditure.

The personal study of plant ecology by Dr. Clements has been supplemented by a considerable body of experimentation under his direction at Santa Barbara and at the Alpine Laboratory. As he approaches retirement he is engaged on the large task of preparing his results of many years for publication. At the same time he is decreasing the experimental effort, which the Institution supports, and rounding out his program.

The Nutrition Laboratory at Boston has had a distinguished history. Located as it is beside the Harvard Medical School, and close to the many biological and medical groups about Boston, it offers excellent quarters for a cooperative program of some sort. The building is adequate and in excellent condition, and at present the valuable work on metabolism being carried out by Dr. Carpenter does not occupy it fully. Under present conditions it is in fact difficult to plan for full and effective utilization of the facilities. In the meantime, support of the work at Boston is being restricted to that sufficient for adequate continuation of Dr. Carpenter's own program.

The Marine Biological Laboratory on the Dry Tortugas has been very serviceable for summer research by visiting biologists, and many papers on marine biology have emerged from this station close to the Gulf Stream. There is no doubt whatever as to its value, but owing to its short season of operation and its remoteness the costs have of necessity been relatively high. It has been re-

luctantly decided that operations there should be suspended, and the equipment put to the best possible use elsewhere. The consequent saving will be material.

The Genetics Record Office at Cold Spring Harbor, formerly the Eugenics Record Office, has been engaged in research on one aspect of the difficult problem of human heredity. Dr. Laughlin will retire from the Institution staff on January 1, 1940. Since the retirement of Dr. Davenport on July 1, 1934, the work of the laboratory has revolved largely about the personal research programs of Dr. Laughlin. It is evident, therefore, that it is time to re-evaluate the way in which the effort of this laboratory may be fitted into the general study of human heredity. Without question this is a subject on which research in this country should be much extended, if plans for a sound, comprehensive approach can be produced. In the meantime the expenditure at the laboratory will be temporarily much restricted.

One of the brightest phases of the history of the Institution has been its long-continued support of the work of Dr. Thomas Hunt Morgan. Not only has this involved the privilege of contributing to the attainments of a very distinguished American; it has also aided in the creation of a group of able geneticists working in the Department of Biology of California Institute of Technology. Dr. Morgan now approaches retirement from the chairmanship of that department. Just as long as Dr. Morgan can carry on personal research, it is important for science that he should do so. It is also excellent for the Institution to contribute to the work of a department of the California Institute which is doing fine and important work. It is expected, however, that, just as in the case

of the seismological program at California Institute, the Institution, having aided in the initial stages of a program, will now gradually withdraw.

In accordance with the previously adopted program, the work of the Department of Meridian Astrometry has been brought to a close.

STAFF RELATIONSHIPS

It is the definite aim of the Institution to enable scientists of outstanding ability to carry on their work under the best possible circumstances, either as members of our own staff or as cooperating scientists having primary allegiance to other organizations. Paternalism, of the sort that interferes unduly with the personal affairs of a staff, should of course always be avoided. Nevertheless, the Institution has a responsibility to its staff which transcends that which is ordinarily present in a commercial organization. This responsibility goes far beyond a mere contractual relation, and it should be continually examined into; for a staff which is overconcerned in regard to security is not likely to be fully creative. As far as is humanly possible, those scientists who are notably extending the boundaries of human knowledge should be shielded from the distracting worries of personal affairs in order that they may do their best work.

There is a difference in this regard between the scientific and the technical or auxiliary staff. To the latter the Institution has full responsibility for handling its relationships in a just and considerate manner; but they remain essentially flexible members of society contributing services which are needed by many organizations. The scientist who has become able to lead the advance in a

particular branch of research, after many years of concentration and specialization, is in an entirely different position. He has, in his relationship with the Institution, greatly decreased his general adaptability, in order to become more effective in a unique field. To him the Institution has a responsibility of another order.

These matters cause little concern when an organization is expanding with ample funds, but they become acute when income from endowments shrinks. The Institution has a duty to push forward the boundaries of knowledge; it has also a more intimate duty in times of stress to protect to the extent of its ability its own members who have for many years fulfilled their obligations.

This does not mean that a program of research once entered into must be carried on unaltered and forever. Such a policy, unless expansion of funds continued indefinitely, would finally lead to a completely static situation. In order to "seek out the man," in order to act as a catalyst, in order to render initial support to precarious projects of great potential scientific promise, terminations must accompany beginnings. The Institution should have the courage and firmness to liquidate as well as the keenness wisely to initiate. Its retirements from matured fields when work is completed, its tapering of support to projects which have arrived at the point where they can be carried on better by others, its withdrawals from support of the research of an individual who retires, should nevertheless always be circumscribed by a strict realization of its responsibility to scientific staff members of long standing. If the problem of shift of emphasis is thus rendered difficult the difficulty should be accepted as an inherent feature of continuing operation.

The salary scale of the Institution will never be com-

parable with that applying to men of similar accomplishments in commercial fields, nor should it be. Rather should it compare favorably with the scale in the outstanding private universities. From this standpoint it is now on the whole reasonable, and as matters now stand it could hardly be improved in any case. When there is opportunity to revise it, if that time comes, it should be examined especially as it affects the younger men. Even our younger men are far more interested in their freedom of scientific attainment and publication and in their ultimate careers than in their immediate salaries; but they should certainly be enabled to live and care for their families in a respectable manner.

While overemphasis on security can become deadening, we do not need to fear any such situation for members of our own group. Their courage is more than that involved in assuming financial risk or meeting physical hazards; willingness to venture, and to risk reputation in order to do so, is an essential attribute without which no scientist proceeds far. With the keen appreciation, therefore, that there is no such thing as absolute financial security, we should attempt to provide, in conjunction with the staff, for the ordinary vicissitudes of existence as far as mechanisms for the purpose are available.

During the year the application of our pension system has been extended, by admitting to it practically all staff members except those on a definitely temporary basis. This has involved the practical abandonment of a classification of regular and temporary membership which was overartificial. The conditions of permanence of employment in the Institution have never been clearly defined, and it is just as well that they should not become more rigid. The staff understands that when changes

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of personnel are necessary they will be carried out reasonably and with a sense of responsibility to those of long service, and such a general understanding is more desirable than a set of artificial rules.

A system of group insurance has also been initiated. Like the pension system, it is financed by staff contributions from salaries, matched by equal contribution by the Institution. It is on a relatively small scale at present, but goes a certain distance toward immediate provision for the family of a deceased staff member.

There is need for reclassification of the staff, not on the basis of permanence of tenure, but in order that eminence may be recognized. The Institution awards no medals and confers no degrees or prizes. It does, by appointment as research associates, recognize individuals in other institutions. In reciprocal fashion, universities sometimes confer the title of professor on members of our staff who are in close collaboration with them, and this is a much appreciated gesture of esteem, which is welcomed when it does not imply distracting duties or obligations. It would be pleasant to be able ourselves to recognize more fully by title the eminence of individuals in our own group. If such procedure be instituted it should involve, as an important element, provision whereby such recognition would connote the approbation of colleagues as well as the estimate of the governing board.

RETIREMENTS

It is a pleasant thing to watch a skillful man take up tools and approach a task of which he is a master. When the time comes for him to lay the tools away, the sadness is mitigated if we can watch him place them in the hands

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of able successors, many of whom he has himself trained in their use. Yet even in the career of an individualist who is so unique that he has no direct successor, there comes a time to retire. It need not, and should not, mean the end of scientific endeavor; death alone should set that time. It is well, however, that retirement from active work should be controlled by rule, and that the rule should be adhered to. Scientific investigation is a strenuous affair, and the scientific world moves at a fast pace. There comes a time when it is better that younger minds should take the burden, the responsibility, and the opportunity. Outside the direct stream there is always yet much to be done, the mature ponderings, the generalization, the philosophical syntheses, the writing of those more leisurely thoughts which are pushed aside under the pressure of rapidly evolving science. The time to turn from one to the other differs from one individual to another, and the best we can do is to base the transition on a faulty calendar age. Even so, it is well that the time should be clearly marked that all may understand. It makes possible an orderly termination of experimentation, in place of an abrupt halt. It anticipates the opening of advancement in continuing enterprises. It ensures the rounding out of programs and their publication for the benefit of others, while it is still possible to plan and to complete.

Several distinguished individuals in the Institution are now engaged in thus closing out their active affairs; and the administration proposes to work with them toward an orderly consummation in full sympathy and appreciation.

CARNEGIE INSTITUTION OF WASHINGTON

PUBLICATIONS

Dr. Frank F. Bunker retired as Editor on February 1, 1939. On September 27, 1939, Mr. T. H. Dillon was appointed to take over the direction of the Office of Publications. It is expected that Mr. Dillon will be concerned as well with other aspects of the Institution's relations with the public, such as exhibits, lectures, and services to the government.

The Institution fills a definite need in the scientific field by the publication of treatises and monographs which present results which could hardly become available to scientists generally through the usual media of publication, such as technical and scientific journals. This program is usually limited to presentation of the works of staff members and research associates. It would be helpful if it could be extended, not only for more complete publication of our own results, but also to enable scientists outside the Institution to produce important treatises not otherwise possible. To do so does not necessarily involve more funds for publication, for our expenditure in this regard is already considerable and we can accomplish something by decreasing costs. Occasionally it is well for the Institution to publish a book which, in addition to its inherent value to learned men, is worth while because of its sheer beauty as a book. On most of our publications, however, it may not be advisable to spend money beyond that necessary to ensure reasonable dignity and adequacy of format, and reasonable endurance, with the prime object of making material readily available to those who can use it. Within this limitation there is still opportunity to extend the scope and value of our publications, and in particular it appears that we can

further increase the ready availability of our publications to research workers in the various fields.

The publication of interpretative material, in order that the public may acquire a better understanding of the scientist, his objectives, and his results, is an involved and difficult matter. We have done much along these lines in the past, and undoubtedly should do so in the future. Such work should always be done well or not at all. Within recent years the presentation of science to the public has expanded greatly, in the press, in magazines, and in popular books, and it remains to be seen how the Institution can best participate in this activity.

PROGRAM OF BIOPHYSICS

The methods and instrumentation of the physical sciences have long been carried over advantageously for attack on the problems of the biological sciences. With the recent advances of physics in the field of atomistics, however, we are in the midst of a new and powerful surge in this direction which promises to accelerate progress in all aspects of biology, and especially in the medical sciences. The invention of the microscope, the advent of X-rays, the discovery of radioactivity all produced striking advances in the earlier days of the art. There is every indication that modern atomistics, with its ability to take apart and rearrange entities not long since thought to be ultimate, will now have a comparable effect. Penetrating rays of new varieties, and especially the tracing of processes by following the course of artificially radioactive atoms and of recognizable isotopes, are already providing the key to baffling biological problems. The rapidly evolving body of knowledge as to the ultimate constitution of physical matter is throwing new light upon

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the behavior of that special kind of matter which is physical in nature but is also alive.

The Institution is in a particularly favorable situation to further such an advance, in which of necessity physicists and biologists must collaborate closely, and for which complex advanced tools of research are imperative. The physicists of the Department of Terrestrial Magnetism, equipped with powerful equipment in their Atomic Physics Observatory, are now recognized as among the leaders in the field of study of the ultimate behavior of the atom. Close by in Baltimore, the Department of Embryology is in direct and cordial relationship with the Johns Hopkins Medical School, where experimental biologists and medical scientists of the highest rank are located and have proved to be intensely interested in this general field. Other biological groups of the Institution, even though at a distance, can collaborate. Moreover, in and about Washington are many educational and governmental organizations which can and will cooperate heartily in a broad program of advancement, notably the United States Public Health Service and the new National Cancer Institute. It thus appears logical that the Washington region should become an outstanding center for research of this nature, and that the Carnegie Institution should contribute notably by furthering in definite manner the contributions of its physicists and the efforts of its biologists in joint programs, and by enhancing the service which can be rendered by the presence of outstanding equipment to scientists in various organizations in this vicinity who are pushing back the limits of knowledge in regard to living things.

A significant start on this broad program was made some time ago. The high-voltage electrostatic equipment

of the Department of Terrestrial Magnetism, of which Dr. Fleming is Director, was built primarily because an extension of our knowledge of the behavior of atoms promised to aid in problems of terrestrial physics, especially in regard to the permanent magnetic field of the earth. While it has been valuable for this purpose, and while there is no intention of curtailing this original program, the equipment is capable, in addition, of furnishing artificially radioactive materials for biological studies. It has done so this past summer to good advantage in several instances.

The Division of Plant Biology, at Palo Alto, is studying photosynthesis under the direction of Dr. Spoeher, and is keen to know much about the way in which a plant handles the carbon dioxide which it draws from the air, and which with water and small supplies of other substances, with the aid of light, it builds into all the complex chemical compounds of which a plant is constructed. This fundamental process, upon which nearly all life depends, has already been discussed in this report. During this past summer equipment from the laboratory at Palo Alto was transferred to Washington, and Dr. Smith and Dr. Tuve, biologist and physicist respectively, attacked the problem jointly. Together they have "labeled" carbon dioxide molecules by rendering them radioactive. The presence of these molecules in any place, even in exceedingly minute quantities, can then be readily measured precisely by electrical means. There have already been tangible results, and carbon dioxide has been thus traced into and out of the carbon dioxide storage reservoir of the plant in the process of photosynthesis. More results will certainly follow.

This electrostatic equipment is not, however, sufficient for all the range of experimentation now thus opening to the physicist and biologist in cooperation. Some years ago Dr. Ernest O. Lawrence, of the University of California, in order to produce artificial radioactivity by bombardment, produced a cyclotron, which is capable of accelerating particles to even greater speeds than those now attainable by electrostatic equipment. The two types of equipment are supplementary rather than competitive, for reasons that need not be gone into here. Numerous cyclotrons have been built in this country and abroad, and Dr. Lawrence has been exceedingly generous in aiding other scientists to profit by his pioneering work. Recently he has completed and put into successful operation a larger and more powerful cyclotron, weighing 225 tons, which has already demonstrated its capacity for speeding certain particles to a velocity corresponding to a fall through a potential difference of 32 million volts. This opens a whole new range of possibilities. After serious study it became evident early this past year that there should be installed on the east coast, close to medical and biological research centers, one of these large machines. The Carnegie Corporation of New York, intensely interested in the type of advance in knowledge which appears probable as a result, has furnished to the Institution \$150,000 with which to construct such equipment. With Dr. Lawrence's continuing cordial aid it has been designed, and it is now being constructed. The cyclotron and an accessory building will be carefully arranged from the point of view of safety, so that physicists and biologists may work together efficiently. For ample protection of all involved it will be largely underground; and careful studies have examined into various aspects of the safe operation of the

most potent equipment, from certain points of view, that man has ever used for his purposes. It is gratifying to realize, in these difficult times, that, as far as one can foresee, the scientific paths which this equipment opens lead not only to an increase of the basic knowledge concerning the nature of our physical environment, but also toward an extended biological knowledge, and in particular toward a better knowledge of man himself, which may indeed serve significantly to aid those who strive to protect him from physical ills.

We have been enabled to express our appreciation to Dr. Lawrence in one interesting way. At his laboratory, in the biological studies carried on in association with his own group, he has need for improved techniques of tissue culture. Dr. Warren H. Lewis and Dr. Margaret R. Lewis, of the Department of Embryology, are leaders in this field; it has been arranged for them to go to Berkeley to lend temporary technical aid in this work. It is to be hoped that as Dr. Lawrence proceeds with his pioneer endeavors, there may be other ways in which he can be extended the generous support which his consistent success fully warrants.

REVIEW

It is customary for the President to summarize the research results of the preceding year. The complete review appears of course in the Year Book, and all that the President can do is to draw attention to outstanding accomplishments and especially significant advances. This year the task is lightened, for each Director of Department and Chairman of Division has preceded his report with a section giving more than the usual sum-

mary and interpretation. It is necessary merely to add a note of emphasis.

The astronomical staff at Mount Wilson continues, in close cooperation with the physicists and engineers of California Institute of Technology, to render aid in an extraordinary program of instrumental development, the outstanding feature of which is the two hundred inch telescope being constructed by California Institute with funds furnished by the Rockefeller Foundation. It is not possible to predict the time when this significant development will be finished, for it depends upon the completion of exceedingly precise grinding and polishing operations which should never be rushed. Dr. Anderson is carrying the burden of this part of the courageous undertaking, and other members of our staff are aiding in the design and construction, together with scientists and engineers all over the country. There has never been a finer example of the generous cooperation of scientific men in a large undertaking.

Not all the significant work in astronomy, by any means, is of a spectacular nature. Much of the body of knowledge is built up of necessity by thousands of photographs over many years. There are great questions about which we are puzzled: the red shift of extragalactic nebulae; the physical state of the surface of the sun and the mechanism of sunspots; the laws governing the constitution of stars in various states, and in particular of novae; and many other questions concerning the structure of the universe. Gradually a body of facts and relationships is being accumulated concerning all of these, which may later form the basis for far-reaching generalizations. An individual advance may often be of startling significance to the astronomer while still drab to the layman. The basis on

which we approach the subject is well stated in the introductory section of Dr. W. S. Adams' report.

Much of this reasoning also applies to our dual approach to terrestrial science. The Geophysical Laboratory, under direction of Dr. L. H. Adams, is gradually accumulating those facts concerning the physical chemistry of the materials that make up the earth's crust, out of which begin to emerge the generalizations necessary for a better understanding of how our earth evolved, in general over long periods, and in detail in recent times. Similarly, the Department of Terrestrial Magnetism long ago extended its efforts far beyond the scope indicated by its title, and is concerned with the whole range of electric and magnetic phenomena found in the earth and its atmosphere. Sometimes interests of these two laboratories converge, as at present in consideration of still higher laboratory pressures, in the hope of throwing more light on the behavior of rocks and on the source of the earth's magnetism and its changes.

Volcanology gives an opportunity to examine a process of earth change in full action. The careful, and dangerous, observations of Perret continue wherever fresh opportunity occurs. In addition, this past winter, we conducted a volcanological expedition to an especially interesting area of Guatemala. The results are promising, and warrant a further expedition this next winter with more complete equipment for gravimetric and magnetic surveying. It appears that these and other geophysical methods which have been so significant in oil prospecting may be capable of yielding valuable information on the nature and progress of volcanoes and of other important processes modifying the state of the earth's crust.

In recent months the deep-sea winch was completed with which we hope to extend into great depths the taking of cores of the ocean bottom. Unfortunately, an expedition for this purpose had to be postponed.

Whenever an observed fact does not fit neatly into a well-established body of knowledge, it warrants especial attention. This is true of the observation at the Geophysical Laboratory of liquids which change color when the pressure is altered, but are surprisingly resistant to temperature change, for usually these factors are parallel in their effects. Some additional concepts concerning the nature of chemical bonding may result.

The Department of Terrestrial Magnetism, in cooperation with George Washington University, held a conference on theoretical physics in the spring, with numerous distinguished physicists present. Out of the conference came, startlingly, an explanation of certain recent experiments in Berlin, and the ideas evolved at the conference were promptly checked by experiment in several places. In the new experiments for the first time man had observed in detail the artificial breaking up of a massive atom into two pieces of comparable size; previous disintegrations had merely succeeded in knocking off small components. Moreover, energy was released in the process. Discussion followed in the literature as to whether the energy thus released by the fissure of uranium might be made available for useful purposes, or misused for destructive purposes. Theoretically possible, such a result has now been shown by experiment to be exceedingly improbable in practice. A wholly desirable result is immediate, namely, an extension of our knowledge of the constitution of the atom.

A similar conference, on the ionosphere, at this Depart-

ment showed the keen interest in many laboratories throughout the country in the constitution of this layer of atmosphere high above us, which has important electrical properties. It is responsible, for one thing, for the progress of long radio waves around the curvature of the earth; in it circulate electric currents responsible for a part of the earth's magnetic field, and these have changes which range from regular daily variations through a variety of disturbances to violent magnetic storms, and show close connection with solar phenomena. The study of these currents and of the aurora—for a long time the only source of knowledge of the ionosphere—is now being advanced by radio experimentation. Radio echoes show the existence of several component layers of ionized air, and instruments at several of our stations now record automatically and continuously the behavior of these.

In comparison with these advances, the experimental study of the atmospheric region below the ionosphere is difficult. A new approach has now been tried in a preliminary way and shows promise. An interrupted searchlight beam is directed upward. Located at a distance, a second mirror with a sensitive photocell at its focus is so mounted as to receive the beam reflected from a point many miles above the earth. Actuated by the light scattered at that point by the rarefied air, the photocell is capable of rendering clear information as to the state of a part of the atmosphere inaccessible to direct examination.

The origin of the earth's main magnetic field and its connected secular changes is of fundamental interest. Promising mathematical methods of analysis have been developed for the latter. The possibility of extending our secular-variation data into the past by determining the magnetic polarization of glacial deposits is now proved,

and it thus becomes possible to follow the earth's magnetic history over at least recent geologic periods.

The Institution continues to correlate a number of cosmic-ray researches in various laboratories, utilizing funds devoted to this purpose by the Carnegie Corporation of New York. The intense study of this baffling bombardment from outer space, which started in Europe many years ago, has attracted the attention of outstanding physicists in this country; for in the cosmic rays are particles traveling at enormous velocity. Not only is their source a complete mystery, but they sometimes produce violent atomic explosions when they collide with a nucleus, and this is a highly catastrophic phenomenon on an exceedingly small scale. Aside from the discovery of new and unexplained connections between cosmic rays and magnetic storms, and of other world-wide effects, a year or two ago it appeared that perhaps this field of research was settling down to slow progress, that the surprises to the theoretical physicist from this source were at an end. Now, however, almost simultaneously in two laboratories, comes the discovery of a new particle of intermediate mass thus produced, of such penetration that it can fly through a foot of lead with little diminution of energy. Just how it is to be fitted into the atomic scheme remains to be seen. Physicists who, only a few years ago, felt that they were nearing a complete theory of atomic structure are now embarrassed by an oversupply of building blocks as they approach the constitution of the nucleus. It is impossible to foresee what may yet emerge from study in this fertile field.

The photosynthetic study in the Division of Plant Biology has already been noted. There is still another aspect of this work which should be especially mentioned. The

amount of light, the exact number of quanta of light to be explicit, which a plant requires to fix a single molecule of carbon dioxide is important. The experimental determination of this ratio is full of difficulty, and hard to guard against error, but it has now been brought to relatively high precision. This having been done, it is found that the ratio is so low that it is inconsistent with the usual energetics theory of the process. When any theory meets a single contradictory fact within its purview, unless the experimentation leading to the fact can be shown to be erroneous, the theory must go, or be modified to include the new observation. In this particular case it appears that the usual theory is only a first approximation. The importance of the matter warrants the great care that is now being given to this particular experimentation.

Scientific research ranges all the way from exploration and rough classification to most meticulous striving for precision of measurement. It is a difficult thing to obtain accurate data concerning all the processes involved in the total heat production of a living organism. Such production is the sum of the amounts of heat developed by intermediary processes going on within the body in which food is either completely burned or changed into other substances. Yet such precise data must be obtained if the study of animal metabolism is to proceed satisfactorily. Dr. Carpenter, at the Nutrition Laboratory in Boston, continues to make significant progress in this important field.

The situation of the Department of Embryology in Baltimore, in close relation to the Medical School of the Johns Hopkins University, is particularly fortunate. It

has had a long and distinguished history and its collection and study of human embryos is unmatched. During the year, by the generous collaboration of Dr. Hertig, of the Harvard Medical School, this collection has been supplemented in unique manner by the addition of specimens of ages estimated to be about eleven days. Needless to say, they are being prepared and examined with extreme care. The Department has also an important program on the parallel examination of macaque embryos. All biology is of course interlinked, and it is worthy of note, as Dr. Streeter points out, that our strictly embryological studies have long been supplemented by experimentation tending to build bridges to such disciplines as cytology, endocrinology, and genetics.

The Department of Genetics has closely collaborated in the past with Dr. Bridges of California Institute of Technology, and his sudden death this year has left a gap which it will be difficult to fill. When he died several important matters were under way, and steps have been taken to render the resultant loss as small as possible. The fundamental results which Dr. T. H. Morgan announced years ago as a result of his experimentation with the fruit fly have led to a remarkable expansion of experimentation with this convenient subject, about which much is now known genetically; and in this work Bridges was an especially able investigator. Comprehensive study of the genetic processes occurring in this one insect has contributed greatly to the solution of the complex problems of genetics. Since the field has been highly productive, it has attracted the attention of laboratories all over the world. Several of our staff attended a genetics conference at Edinburgh this past summer, where this was an important aspect of the broad discussion. Unfortunately much

of the work there reported is now interrupted. This renders it highly desirable that American geneticists pick up the burden as far as they may; one aspect of this problem which merits especial attention is the preservation of important mutant stocks.

Our laboratories at Cold Spring Harbor continue also their important work on the genetic relationships of leukemia, and on endocrinology. The fascinating study of the artificial production of polyploidy in plants by Dr. Blakeslee warrants special attention. When, many years ago, the work on pure strains of corn was initiated at Cold Spring Harbor, one could hardly have visualized its being followed by intense commercial experimentation leading up to the economically important hybrid corn of the present day. Similarly, the deliberate shuffling of chromosomes, under chemical stimulation and subsequent hybridization, may lead far afield. It is certainly of great interest merely from the light it throws upon the whole genetical problem, if for no other reason. Dr. Blakeslee is now rounding out his experimental treatment of this matter with results which he relates in detail.

Dr. Kidder's report on historical research emphasizes the care that is being given to critical study of the program as a whole and its interrelations. This is particularly true of the effort, during several years past, to approach the study of a historical matter by means of the interaction of several diverse disciplines. This has been frankly an experimental procedure. The primary archaeological research on the ancient Maya civilization is being supported by varied studies—biologic, linguistic, economic, social, and the like—of the Maya of today. In addition the effort is made to link together architectural, hieroglyphic, geological, climatological, and other aspects

of the evidence as to what preceded. The advance that has been made in the techniques of physics and chemistry has reverberated into many other sciences. By their nature the historical sciences cannot profit as fully as other branches of science by the adoption of methods, materials, instruments, and processes from such fields, and yet it is sometimes possible to borrow thus to advantage. The preservation of documents is aided by cellophane coatings; they are rendered legible under difficulties by the use of ultraviolet light; modern indexing methods aid in utilizing the voluminous material necessary to the historian. One interesting example of such transfer of techniques is to be found in the use of the petrographic microscope, the methods of microchemistry, and spectrographic analysis in the examination of pottery and glazes carried on by Dr. Shepard. The problem of the historian, and especially of the archaeologist, is often akin to that of the detective as pictured in popular stories, where every means of producing facts in evidence needs to be employed to ferret out a puzzling situation. Of course there is another phase of the work of the historian which follows, and which is even more severe in its demands. This is the work of synthesis. Once the threads are followed out, the artifacts identified and classified, the documents searched and extracted, it remains to build again an inter-related whole; for the benefits of research in history come fully only when we are led to understand, for our guidance as we face the future, the things that have passed away.

The work of our Research Associates, and the research performed by reason of grants administered by the Institution, is so varied that complete summary is beyond the scope of this report. One result only will be chosen for

especial comment. The study of early man took a great stride when, in Java in 1937, there was discovered a part of the skull of *Pithecanthropus*; and yet it was only a fragment. Now there is a further discovery. Dr. von Koenigswald, following a careful line of investigation over several years, has uncovered additional fragments, and in particular the jaw with dentition in place. The significance of this find in the investigation of man's origins is discussed in Dr. Merriam's report. It is certainly, in its field, the most important discovery in many years.

COMMITTEES OF THE TRUSTEES

The Trustees' committees on the several aspects of the research of the Institution have been in operation only since the first of the year, and thus far they have functioned only in an informal manner. While there have not as yet been stated meetings and formal recommendations, the existence of these committees has already been distinctly helpful. The President has had numerous occasions to consult with the chairmen of these committees concerning problems facing the Institution in the several fields, and many informal conferences with members of the committees have followed. It is felt that this procedure can be continued to advantage, and it is hoped that all members of the Board will find this a welcome way of becoming acquainted in an intimate manner with some aspect of the work of the Institution. Certainly the President has valued the advice and counsel thus rendered available to him. As major questions arise, such as those in regard to changing emphasis on fields of research or large-scale new projects, it is hoped that these committees will become still more active.

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HENRY SMITH PRITCHETT

Henry Smith Pritchett died on August 27, 1939, and the career of an outstanding figure in American science and education came to a close. His activities in the Carnegie Institution of Washington were many. Elected a member of the Board of Trustees on December 11, 1906, he became a member of the Finance Committee in 1909, a member of the Executive Committee in 1914, Chairman of the Executive Committee in 1933, and Vice-Chairman of the Board of Trustees in 1927. All these responsibilities he carried until his resignations from his offices in 1935, and from the Board in 1936, were accepted, by reason of ill health.

Dr. Pritchett's close association with Mr. Carnegie, and his numerous activities in other Carnegie organizations, heightened and broadened his influence upon the policies of the Institution.

To his many executive undertakings Dr. Pritchett brought a rare combination of imagination and rigorous logic which was the basis of his early accomplishments as an astronomer. A continuing emphasis upon the highest type of scientific accomplishment accompanied his untiring efforts to render more secure the lives of all scientists and educators. The Carnegie Institution of Washington occupies its present place in American science because of the influence of many individuals of high ideals, of whom Dr. Pritchett was long a notable and striking example.

REPORTS ON DEPARTMENTAL INVESTIGATIONS

ASTRONOMY

MOUNT WILSON OBSERVATORY

TERRESTRIAL SCIENCES

GEOPHYSICAL LABORATORY

DEPARTMENT OF TERRESTRIAL MAGNETISM

BIOLOGICAL SCIENCES

DIVISION OF PLANT BIOLOGY

DIVISION OF ANIMAL BIOLOGY

HISTORICAL RESEARCH

DIVISION OF HISTORICAL RESEARCH

MOUNT WILSON OBSERVATORY

WALTER S. ADAMS, DIRECTOR

FREDERICK H. SEARES, ASSISTANT DIRECTOR

The work of the Observatory during the past year may for convenience be listed under three main headings: the sun and the solar system; the stars of our stellar system and the material which lies between them; and the extragalactic nebulae—more or less fully developed systems of stars which lie far outside our own system, dotted throughout space like islands out to the limits reached by the largest telescopes. This observable portion of space has at present a radius of roughly half a billion light-years. It is filled with matter in almost every conceivable form, stars, clusters, organized stellar systems like our own, clusters of systems, finely divided cosmic dust, coarser material such as strikes the earth in the form of meteorites, and huge volumes of tenuous gas, often shining through excitation from a neighboring star. In this complex aggregation the star is the most important unit, for it is a self-contained machine giving out great quantities of light and heat, probably maintained through atomic transformations in the material of which it is composed. With the single exception of the sun, however, the stars are so extremely distant that we must depend upon the sun itself and the changing phenomena of its disk for much of our information regarding stellar processes.

As a star the sun is of very moderate size and brightness, but it is typical of an immense number of stars in our system having the same temperature and doubtless very similar physical conditions. Since it is the source of life and heat for the whole planetary system, every important event upon it is of importance to the earth. So from every

point of view the study of the sun is fundamental to astronomy, and it has always occupied an important place in the work of the Observatory. The Mount Wilson records of the state of the sun's surface, now reaching back more than 30 years, form an exceedingly valuable collection of material for reference and statistical studies, which is frequently consulted by astronomers from other parts of the world.

During the past year the sun has been in an exceptionally active state, and sunspots have been large and numerous. The sunspot activity has been at least as high as in 1937, and judged by a well-known index, the Wolf number, the month of July 1938 was the most active month in the past 68 years. Although the maximum of the 11-year cycle of sunspot activity has almost certainly passed, it is clear that the present maximum is of the broad type in which two or three successive years are characterized by nearly equal numbers of spots.

Since the discovery of magnetic fields in sunspots by Dr. Hale in 1908, observations of the strength and direction of these fields have been continued regularly at Mount Wilson. The remarkable discovery of the reversal of sign of the field with the spot-cycle, first suspected in 1912 and confirmed in 1923, has been borne out fully by the observations of the present cycle; and a notable contribution to the study of this fundamental phenomenon in solar physics was the publication by the Institution in 1938 of the magnetic classification of 2174 spot-groups observed in earlier years by Hale and Nicholson.

The high state of solar activity has

also favored investigations of the spectrum of sunspots, and by observing suitable spots with specially designed apparatus the range in wave length over which such studies can be made photographically has been extended more than 30 per cent. Further, the occasional brilliant outbursts of light occurring in the sun's atmosphere near sunspots, which in recent years have been found to produce magnetic storms upon the earth and radio fadeouts, are naturally more frequent during periods of high sunspot activity. Eighteen such disturbances have been studied in detail, with especial reference to the time and duration of the outburst and the nature of the radiation given out by these regions of intense local activity.

Many other solar researches have been continued or completed, bearing on such varied problems as the number of the small, bright granulations visible on the surface of the sun, for which a photographic study gives a total for the whole sun of 950,000; the change in the intensity of the sun's radiation across its disk; the amount of ultraviolet light given out by the sun; and the intensity of the light of a sunspot relative to that of the sun in different colors of the spectrum.

An instrumental development of interest is that of a photoelectric amplifier by means of which the amount of light in the spectral lines relative to that in the continuous background of the solar spectrum can be measured directly without the complications introduced by the photographic process. These relative intensities are basic data for a whole series of problems relating to the composition and state of the sun's atmosphere. Especially interesting is the reconstruction of the 60-foot tower telescope, which after 30 years of use has been rebuilt in such a way as to permit uninterrupted observations and the automatic registration of many solar phenomena. A synchronous motor drive with a mechanical

speed change has been supplied and also a photoelectric guiding control which automatically corrects all displacements of the sun's image from its normal position.

When we pass from observations of the sun to those of planets and satellites in our solar system, an outstanding result is the discovery by Dr. Nicholson in July 1938 of two additional satellites to the planet Jupiter, bringing the total number in this complicated system to eleven. Satellites X and XI are extremely small bodies, among the smallest known within the solar system, with diameters calculated at 15 and 19 miles, respectively, but they attract attention both because of their motions and because of the question of their origin. Whether they once formed a part of Jupiter or were captured by the great planet is a problem of exceptional interest.

Studies of the surface features of the moon have been in progress for several years under the charge of Dr. Wright of the Geophysical Laboratory of the Institution. The difficult but interesting question of the material composing the moon's surface has received a fairly positive answer. It cannot be exposed solid rock, but must be porous like pumice or light dust, which quickly loses the heat it receives from the sun. Much of the evidence for this conclusion is derived from a comparison of the quality of the light (polarization) reflected from the moon's surface with that from selected terrestrial materials. In addition to such observations, the moon has been photographed at brief intervals during an entire lunation. Study of the numerous negatives thus obtained by stereoscopic projection and other means has contributed data needed for the preparation of an adequate topographic map of the moon.

In the vast field of the stars the investigations of the year have been many and varied. They range from determinations of distances, motions, and brightness of

the stars to studies of the distribution of light within the lines of their spectra and estimates of the relative proportions of the different elements composing them. A few of these studies may be mentioned as illustrations.

The luminosity of a star, the actual amount of light it gives out, is a matter of great importance in physical astronomy. It may be determined readily if the distance of the star is known, or by a study of its spectrum, or, in the case of certain stars whose light varies, from the period of light-variation. Further, for groups of stars the average luminosity may be obtained by calculations based upon their motions across the sky and toward or away from the earth. All these methods have been used in recent work at Mount Wilson. Of especial interest is the discovery of some stars of remarkably low candle power; several of these give out less than one ten-thousandth as much light as the sun, and one or two as little as one fifty-thousandth. At the other extreme, the average output for the most luminous stars, which have temperatures of the order of $20,000^{\circ}\text{C}$, is about 30,000 times that of the sun. The quantity of light sent forth by the sun is, therefore, roughly midway between that of the faintest and that of the most luminous stars.

The fact that our galaxy, the great system of stars to which our sun belongs, is in rotation, although long suspected, has been proved only within recent years. Various determinations of the constants of this motion have been made; the most recent one, by Professor Joy, utilizes the fainter members of a class of very distant variable stars. The distance to the center of rotation is found to be about 33,000 light-years; the circular orbital velocity of the sun, about 300 kilometers per second; and the period of revolution of the sun about the center, 207,000,000 years.

Observations of the spectra of stars

have been too numerous to mention in detail. Of especial interest are the studies of the analyzed light of variable stars of several different classes, of stars showing bright lines in their spectra, of the very dense stars of high temperature but low luminosity known as "white dwarfs," and of some of the brighter stars which have been investigated with spectrographs more powerful than any hitherto available for stellar observations. Accurate measurements of the intensities of the spectral lines with the microphotometer are yielding valuable data on the temperatures and atomic constitution of all these objects.

Lying between the stars, especially in the neighborhood of the Milky Way, are great quantities of finely divided cosmic dust involved in a stratum of interstellar gas. The dust affects light of different colors differently, scattering the blue and violet light which seeks to penetrate it much more than it does the red light. As a result, the light passing through these clouds of cosmic dust is reddened in color, and the thicker the clouds, the greater the reddening. Such a cloud reddens appreciably the brighter stars in the vicinity of the North Pole. It has a thickness of about 1000 light-years and its nearer edge is only some 200 light-years distant. Another investigation of stellar colors, which now includes nearly 1500 stars measured with a photoelectric cell, shows that even some of the brighter regions in the Milky Way would appear twice as bright were no obscuring material present. A second important conclusion is that the interstellar gases, which produce definite lines superposed upon the spectra of many of the distant stars, are closely associated with the cosmic dust. The gases as well as the dust occur throughout a widely extended stratum, but the distribution of both is highly spotted and irregular.

The narrow lines produced by the atoms of absorbing interstellar gases are

themselves a fruitful field of research. Investigations at Mount Wilson during recent years have more than doubled the number of such lines and added three more elements to those known to exist in interstellar space. Two studies have dealt with the physical state of these gases and the distribution of the gaseous clouds, and a third has resulted in a new determination of the abundance of the electrons and atoms of the identified elements. Sodium is found to be some 30 times as abundant as calcium and several thousand times as abundant as titanium.

Recent discoveries of supernovae have centered attention on these extraordinary stars, which burst forth from quiescence and quickly attain a luminosity of a hundred million or more times that of the sun. They are observed occasionally, here and there in the multitudinous remote stellar systems; but within any single system they usually appear only at intervals of hundreds of years. Although no such outburst has been noted in our own system for several centuries, the so-called Crab Nebula in the constellation of Taurus apparently is the remnant of a supernova which appeared in that part of the sky in the year 1054. Much stronger evidence of identity has been found in the expansion of the nebula, which was discovered some years ago. Recent measurements of changes within the nebula fix approximately the date of the beginning of the expansion, which agrees as well as could be expected with that of the outburst of the nebula.

With the discoveries of the past year, made mostly at Palomar Mountain by Dr. Fritz Zwicky of the California Institute of Technology, the total number of known supernovae has risen to 30. The analysis of the light of several of these stars shows that their spectra are remarkably similar and undergo similar changes as the light diminishes and fades away.

In general the spectrum consists of a series of very broad bright bands, the width of which gradually decreases for about two weeks after the star has reached its maximum brightness and then remains constant. A noteworthy fact is the appearance at an early stage of a slowly but steadily increasing displacement toward the red of the bands in the blue region of the spectrum, which in one instance was followed for nearly a year. The cause of the displacement and even the identification of the bands are as yet quite uncertain. In fact, the whole question of the interpretation of the spectra of supernovae is still an unsolved problem.

The more comprehensive studies of extragalactic systems, which constitute the third great field of investigation, have dealt with classifications according to the sequence of nebular forms; with surveys of the numbers of nebulae required to define more accurately the zone of avoidance within which the nebulae are hidden by clouds of cosmic dust; with the light-curves as well as the spectra of supernovae; with the motions and rotations of nebulae, and the motion of our system of stars relative to the nebulae. Intensive observation of two faint systems of stars discovered at the Harvard College Observatory in the constellations of Sculptor and Fornax show them to be systems of comparatively low luminosity, located at distances of 300,000 and 600,000 light-years. They probably belong to the local group of extragalactic nebulae of which our stellar system is a member.

Future work on the structure and dynamics of extragalactic systems will be considerably influenced by the discussions of a conference held at the Observatory in June 1939. Both theoretical and observational investigators took part, among them Dr. Lindblad, Director of the Stockholm Observatory, Dr. Oort of the Leiden Observatory, and Dr. Mayall

of the Lick Observatory, as well as members of the Observatory staff. With a large amount of photographic and spectroscopic evidence available for reference, working hypotheses could be reviewed and programs of observation effectively planned. The urgent need is a more detailed spectroscopic analysis of the light of distant systems, an investigation now to be attempted with improved instruments and photographic plates.

Almost every physical investigation of the sun or stars requires at some period for its interpretation the assistance afforded by data acquired under controlled conditions in the laboratory. This is especially true of studies of spectra or of radiation in general. As an illustration, we cannot determine the relative numbers of atoms of the different elements present in the atmosphere of the sun or a star unless we know certain factors which govern the numbers of atoms contributing to the formation of related lines in a spectrum. The evaluation of these factors is a laboratory undertaking, and experiments now under way demonstrate again the vital part played by the electric furnace and other laboratory equipment in solving stellar problems. In fact, laboratory investigation is the first step in unraveling the complicated spectra which provide such a wealth of information regarding conditions in the stars.

An essential part of the Observatory's work, whether at the telescope or in the laboratory, has always been the adapta-

tion and development of auxiliary apparatus which would contribute to the success of the observations. The new equipment of the 60-foot tower telescope has already been mentioned. Other instances are improvements in diffraction gratings and in the design of spectrographs. The remarkable results attained by Professor R. W. Wood and others in concentrating so large a part of the light from a diffraction grating in any desired order has made the grating a strong rival of the prism in spectroscopic observations of faint light-sources. During the construction of the new ruling machine in the Observatory's shops, which is now well advanced, much experimental work is being done on different types of ruling surface and on methods of shaping the diamond ruling points so that the concentration of light will meet specified requirements. The principle of the Schmidt telescope, which was devised only a few years ago, is finding wide application in cameras for spectrographs. Its important features are great light-gathering power and sharp definition over a large field. Two such cameras, constructed for spectroscopic observations at the 100-inch telescope, present the extremes in this type of design. One utilizes a 36-inch mirror with a focal length of 114 inches; the other, with an aperture of about 2 inches, has a focal length of only 1.3 inches. Both have been designed to obtain specific results—spectra of bright stars on a very great scale, and spectra of objects so faint that scale must be reduced to the lowest limit permissible.

STAFF

The administration of the Observatory has remained in the hands of Dr. Walter S. Adams, Director, and Dr. Frederick H. Seares, Assistant Director. Dr. Adams has continued his investigations of stellar spectra with high dispersion and of spectroscopic absolute magnitudes, and Dr. Seares has given much time to the photo-

metric extension of the stars of the Polar Sequence and the study of the color excess of stars in the polar region. Dr. Seares has also continued his editorial supervision of Observatory publications.

Dr. John A. Anderson, as Executive Officer of the 200-inch telescope project, has devoted most of his time to optical

and mechanical problems relating to this great instrument. Dr. Arthur S. King, Superintendent of the Physical Laboratory, has completed a temperature classification of the spectrum of europium, and in collaboration with Dr. Russell, has made a term analysis of the spectrum of the neutral atom. Dr. Edwin Hubble has been engaged in analyzing his extensive material on the distribution, brightness, and forms of the extragalactic nebulae. Dr. Walter Baade has been occupied with nebular investigations, photometric studies of star clouds, and magnitudes of faint stars and supernovae. Dr. Paul W. Merrill has carried on spectroscopic researches on early-type stars, long-period variables, and stars showing emission lines in their spectra. Interstellar lines have been studied quantitatively in many stars by Dr. Roscoe F. Sanford and Dr. Olin C. Wilson with interesting results. Professor Alfred H. Joy, Secretary of the Observatory, has applied his observations of the motions of 156 Cepheid variables to the determination of the constants of galactic rotation. Dr. Theodore Dunham, Jr., has been engaged in the measurement of the contours and intensities of lines on high-dispersion stellar spectrograms, and in a new determination of the abundance of atoms and electrons of various elements in interstellar space. Dr. Seth B. Nicholson, in general charge of solar investigations, has continued polarity studies of sunspots and observations of bright chromospheric eruptions and many other solar phenomena. He has also made numerous observations of the positions of Jupiter's satellites X and XI, discovered by him in the summer of 1938. Mr. Harold D. Babcock has designed and used a concave-grating spectrograph at the Solar Laboratory to extend the observable sunspot spectrum throughout the interval $\lambda 3100\text{--}\lambda 11400$. The same instrument has been utilized for wave-length determinations in the ultraviolet and infrared

regions. Dr. Adriaan van Maanen has made a special search for stars of very low luminosity and has added several interesting objects to this class of stars. From the data now accumulated he has investigated the space density of stars near the sun. Dr. Gustaf Strömberg has continued his observations of the radial velocities of stars in the Selected Areas and has completed statistical investigations of absolute magnitudes of dwarf F, G, and K stars. Mr. Milton L. Humason has been engaged in the study of the red shift and the rotation of a selected group of extragalactic nebulae, and has photographed the spectra of numerous faint stars with the nebular spectrograph. Dr. Rudolph Minkowski has studied the spectra of supernovae and white dwarf stars. Dr. Ralph E. Wilson has derived the absolute magnitudes of several groups of stars of different spectral types from proper motions and radial velocities. He has also redetermined the zero point of the period-luminosity relation for Cepheid variables. Dr. Edison Pettit spent a portion of the summer of 1938 at the McMath-Hulbert Observatory engaged in solar observations and has continued related investigations at Mount Wilson. Dr. Robert S. Richardson has made a special photometric study of bright chromospheric eruptions and has carried on several other solar investigations. Dr. Robert King has devoted his time in the physical laboratory to observations with the electric furnace and determinations of the relative f -values for selected lines and multiplets in the spectrum of neutral iron, titanium, nickel, and vanadium. Mr. Joseph Hickox has continued solar observations on Mount Wilson. Mr. William H. Christie has shared in the stellar spectroscopic investigations and has made photometric measures of the magnitudes of globular star clusters. Mr. Hickox and Mr. Christie have given the regular public lectures on Friday eve-

nings throughout the year. Mr. Edison Hoge has assisted in the solar investigations on Mount Wilson and has given much time to general photographic work and the improvement of reproduction processes.

In the Computing Division Miss Louise Ware has given most of her time to studies of solar and stellar line-intensities with the microphotometer. Mrs. Elizabeth S. Mulders has been engaged in measurements of sunspots, flocculi, and other solar phenomena and in the compilation of data relating to solar activity. Mr. E. F. Adams has continued his measurements of spectra, more especially those of the rare earths photographed by Dr. A. S. King with the electric furnace. Miss Mary C. Joyner has collaborated with Dr. Seares in photometric studies of stars in the North Polar region. Miss Cora G. Burwell has devoted her time to the study of stellar spectra under investigation by Dr. Merrill. Miss Myrtle L. Richmond has continued measurements of solar plates and positions of Jupiter's satellites, and has done much general computing. Miss Ada M. Brayton and Miss Alice L. Lowen have measured and reduced stellar spectrograms, and have cared for the records and computations required in this extensive field of investigation. Miss Dorothy J. Carlson has divided her time between stellar spectroscopy and the preparation of records relating to surveys of nebulae. Mrs. Mary Coffeen has assisted Mr. Babcock in his studies of sunspot spectra and the wave lengths of solar spectrum lines. Miss Elizabeth Connor, Librarian of the Observatory, has aided in the editorial work and the preparation of material for publication.

Dr. Joel Stebbins, Research Associate of the Carnegie Institution and Director of the Washburn Observatory, spent the month of June and a portion of July 1938 at the Observatory, engaged in measure-

ments of the radiation of early-type stars with the photoelectric photometer. In this work he was assisted by Dr. Albert E. Whitford, who continued the observations during the remainder of the summer. Dr. Henry Norris Russell, Research Associate of the Carnegie Institution and Director of the University Observatory, Princeton, carried out an analysis of the spectrum of neutral europium during his stay in Pasadena in the autumn of 1938. He also did further work on his investigation of the errors of trigonometric and spectroscopic parallaxes.

Dr. Fred E. Wright, of the Geophysical Laboratory of the Carnegie Institution, assisted by Mr. Hamilton Wright, made an extensive series of photographs of the moon with the 100-inch telescope and Ross correcting lens during the summer of 1938. Measurements of polarized radiation from the moon's surface were also continued. Dr. Frank E. Ross, of the Yerkes Observatory, devoted several months, while in Pasadena, to computations of lenses to be used for spectrographic work and direct photography with the 100-inch and 200-inch telescopes. Dr. John C. Duncan, Director of the Whittin Observatory, spent the period between July 4, 1938 and February 5, 1939 at the Observatory and made numerous direct photographs with the two large reflectors. Dr. J. H. Oort, of the University of Leiden, carried on observations of extragalactic nebulae at Mount Wilson during the months of May and June 1939. Dr. Jaako Tuominen, Research Fellow from Helsinki, Finland, was in Pasadena during two of the winter months and continued his researches in theoretical astrophysics. Mr. William Miller has continued throughout the year his observations with the 10-inch photographic telescope and objective prism and has discovered numerous stars showing emission lines in their spectra. Mr. William H. Hoover, of the Smith-

sonian Institution, spent the summer of 1938 on Mount Wilson and, in addition to measurements of solar radiation, obtained spectral energy-curves of some of the brighter stars.

Among others who have visited the Observatory for shorter periods of time have been Dr. C. G. Abbot, Secretary of the Smithsonian Institution, Dr. Bertil Lindblad, Director of the Stockholm Observatory, Dr. Knut Lundmark, Director of the Lund Observatory, Dr. Nicholas Mayall, of the Lick Observatory, Dr. G. W. Morey, of the Geophysical Laboratory of the Carnegie Institu-

tion, and Dr. Karl Wurm, of the Astrophysical Observatory at Potsdam.

The members of the Observatory staff attending the annual meeting and exhibit of the Carnegie Institution at Washington in December 1938 were Messrs. Adams, Merrill, and Nicholson. Dr. Dunham spent the months of May and June at the University Observatory, Oxford, England, where, in collaboration with Dr. H. H. Plaskett, Director of the Observatory, he tested a new form of photoelectric amplifier for measuring directly the intensities of solar spectrum lines.

OBSERVING CONDITIONS

During the year July 1, 1938 to June 30, 1939, stellar observations were made on 295 nights, 5 more than the 27-year average. The number of part-time nights, however, was unusually large, 98 against an average of 86. The number of clear days was 220, of partly cloudy 95, of cloudy 50. With the inclusion of occasional drawings made through thin clouds, solar observations were obtained on 332 days.

The maximum temperature was 99° F, on August 1, 1938; the minimum, 17° F, on February 9, 1939. The total snowfall was 36.5 inches; the total precipitation, 27.86 inches, 5 inches less than the average for 35 years.

The accompanying table gives the monthly record of observations with the 60-inch telescope during the year. The number of visitors using the telescope on

Friday evenings, when it is open to the general public, is also given and may be of interest.

MONTH	OBSERVATIONS			VISITORS
	All night	Part of night	None	
1938:				
July.....	26	3	2	1,917
August.....	23	6	2	1,837
September..	18	5	7	987
October.....	12	13	6	854
November...	17	10	3	980
December...	9	8	14	614
1939:				
January....	10	11	10	276
February...	4	12	12	160
March.....	15	10	6	668
April.....	16	9	5	662
May.....	23	5	3	934
June.....	24	6	0	1,839
Total.....	197	98	70	11,728
Mean 27 years	204	86	75	

SOLAR RESEARCH

The routine program of daily observations of sunspots, prominences, and flocculi and the daily records of the intensity of ultraviolet radiation and of the direction and the horizontal intensity of the earth's magnetic field have been continued.

Daily photographs of the sun have

been sent semimonthly to the U. S. Naval Observatory to complete the record of positions and areas of sunspots published in the *Monthly Weather Review*. The daily numbers of sunspots and groups were communicated weekly to Science Service at Washington until November. The service was then discontinued be-

cause it duplicated certain monthly reports which seemed to meet the practical requirements. Duplicate spectroheliograms have been supplied regularly to the Kodaikanal and Meudon observatories as a part of the plan of cooperative solar observation. The approximate positions, field strengths, and magnetic classifications of all sunspots have been printed regularly in the *Publications of the Astronomical Society of the Pacific*. Estimates of daily character figures of solar activity from calcium and hydrogen flocculi have been sent to Commission 10 of the I. A. U. for publication in its *Bulletin for Character Figures of Solar Phenomena*. These estimates have also been published in *Terrestrial Magnetism and Atmospheric Electricity*. The data were compiled and prepared by Nicholson and Mrs. Mulders. The positions and intensities of bright chromospheric eruptions have been communicated by Richardson to Commission 11 of the I. A. U. for publication in the *Bulletin for Character Figures* as a part of the cooperative program of observation with the spectrohelioscope.

SOLAR PHOTOGRAPHY

Solar photographs have been made by Hickox, Hoge, Nicholson, and Richardson on 315 days at the 60-foot tower telescope. Direct solar photographs are usually taken early in the morning and followed by spectroheliograms made at the 60-foot, the 18-foot, or the 7-foot focus, according to the quality of the seeing. The spectroheliograms with the 7-foot focus objective are on motion-picture film used in an automatic recorder, which is easily exchangeable with the plateholders and runs continuously unless larger spectroheliograms are being made or the spectrohelioscope is in use. The exposures are of from one to two minutes duration, separated by intervals of from one to two minutes; and

within these limits the sun was under observation for an average of 6 hours on 315 days during the year. The approximate number of exposures of each kind was as follows:

Direct photographs	630
<i>Hα</i> spectroheliograms of spot-groups, 60-foot focus	230
<i>Hα</i> spectroheliograms, 18-foot focus..	1,150
<i>Hα</i> spectroheliograms, 7-foot focus..	29,000
K2 spectroheliograms, 18 foot focus..	820
K prominences, 18-foot focus.....	860

SUNSPOT ACTIVITY

During the calendar year 1938, solar observations were made at Mount Wilson on 311 days, on all of which spots were visible. The monthly means of the numbers of groups observed daily for the past two and one-half years are shown in the accompanying table.

MONTH	DAILY NUMBER		
	1937	1938	1939
January.....	10.7	8.8	8.4
February.....	12.0	9.7	7.8
March.....	9.5	7.0	8.1
April.....	8.3	8.7	10.8
May.....	8.6	11.3	11.4
June.....	9.8	9.1	10.2
July.....	13.6	13.3	
August.....	12.0	12.3	
September.....	9.1	7.9	
October.....	10.0	9.0	
November.....	7.8	9.0	
December.....	7.9	8.4	
Yearly average..	9.9	9.5	

During 1938 the sun was very active, by most criteria almost as active and by some even more active than in 1937. The yearly average of the numbers of sunspot groups observed daily at Mount Wilson was a little less than in 1937, but the number of individual groups was 10 greater and set a new record of 547. Of this number 295 were in the northern hemisphere and 252 in the southern. In 1937 the northern hemisphere was also

the more active, the corresponding numbers being 285 and 252, respectively. July was the most active month of the year, not quite so active as July 1937 according to the numbers of groups observed daily at Mount Wilson, but more active according to the Wolf sunspot numbers from Zürich. Judged by its Wolf number, 166, July was in fact the most active month since May 1870.

SUNSPOT POLARITIES

When possible, the magnetic polarities in each spot-group have been observed at least once. The accompanying table indicates the number of spot-groups classified from July 1, 1938 to June 30, 1939. "Regular" groups in the northern hemisphere are those in which the preceding spot has N (north-seeking) polarity and the following spot S polarity. In the southern hemisphere the polarities are reversed.

HEMISPHERE	POLARITY		
	Regular	Irregular	Unclassified
North.....	203	7	94
South.....	173	9	70
Whole sun....	376	16	164

THE WILSON DISPLACEMENT IN SUNSPOTS

In 1769 Alexander Wilson of Glasgow noted that the umbra of a sunspot close to the limb appears displaced toward the center of the disk relative to the penumbra, as though the spot were a depression. The reality of this displacement has often been questioned. Observing visually with a 6-inch Clark refractor in Pasadena, Pettit has found the displacement in practically all of 26 spots seen within 30" of the limb. It also shows on recent photographs taken in orange light, $\lambda 0.58 \mu$, of 50 spots within 1' of the limb and is sometimes noticeable at distances of 2' or more from the limb. A ring of

faculae surrounding the penumbra, at an elevation of one to two thousand kilometers above the photosphere, apparently is the principal cause of the phenomenon.

On three occasions during the visual observations an unusual appearance was noted. The inner margin of the penumbra was defined by a bright cordlike structure extending over a considerable arc. The luminous arc lasted only a few hours.

GRANULAR STRUCTURE OF THE PHOTOSPHERE

The use of an orange filter in taking the daily photographs of the sun has so improved the quality of the plates that many of them can now be used for studies of photospheric structure. Counts of the granules by Pettit give for the entire solar surface a total of about 950,000, a value 25 per cent less than that sometimes reported. For seemingly perfect granules the diameter ranges from 0'5 to 2'5.

CHROMOSPHERIC ERUPTIONS

Richardson has derived intensities for eighteen bright chromospheric disturbances for which the Mount Wilson records are complete from beginning to end of the outburst. The data depend on measured areas of the flocculi and eye estimates of their brightness, and should be useful in studying radio records made during fadeouts. Most outbursts rise rapidly to a maximum, then decline slowly. Sometimes a second maximum occurs, occasionally greater even than the first. A chromospheric disturbance of intensity 2 or 3, if accompanied by an emission of the Lyman α line five times stronger than that of $H\alpha$, would increase the normal radiation within the interval $\lambda\lambda 1100-1300$ by 60 per cent.

Spectrograms of five bright chromospheric disturbances made with a concave grating and an all-mirror optical system (dispersion 8.8 Å/mm) show in

emission only $\lambda 10830$ of helium, the Balmer lines to H_t , and ionized calcium. There is no evidence of emission at the Balmer series limit, nor that black-body radiation plays any part in the disturbance.

DARKENING AT THE LIMB

In 1933-1934 Pettit obtained numerous records of the intensity of the total radiation across the solar disk. The drift-curves were made with a $\frac{1}{4}$ -second galvanometer and a thermocouple provided with gold-leaf receivers. Reference marks for each second are registered upon the records. Measurement of these curves has given the intensities shown in the accompanying table, of which the last value is doubtful:

Distance from center (Radius=1)	Intensity
0.00.....	1.00
0.50.....	0.95
0.70.....	0.87
0.80.....	0.82
0.90.....	0.73
0.95.....	0.67
0.96.....	0.65
0.97.....	0.62
0.98.....	0.58
0.99.....	0.50
1.00.....	(0.30)

ULTRAVIOLET ENERGY-CURVE OF THE SUN

Measurements of the energy-curve of the sun in the interval $\lambda 0.7-0.292 \mu$ obtained by Pettit on eleven days in May and June 1939 agree reasonably well with those made with the same equipment at Tucson in 1931. They confirm the approximately uniform intensity from $\lambda 0.38 \mu$ to $\lambda 0.325 \mu$ found in that investigation. The measured atmospheric coefficients are nearly the same as those of Abbot. A minor result is that aluminized surfaces exposed to sunlight for long periods show a secular reduction of reflecting power in the ultraviolet.

SOLAR AND SUNSPOT SPECTRA

Eighty-six spectrograms have been obtained by Babcock with the 75-foot and the 21-foot spectrographs at the Hale Solar Laboratory for the further separation of atmospheric and solar lines and for improving the wave lengths in the ultraviolet and the infrared. The use of a modern filter has given spectrograms for the ultraviolet limit superior to those of Rowland. The red limit is $\lambda 12200$. Babcock has also made 27 spectrograms to test a new arrangement of the polarizing apparatus used for the study of solar magnetic fields which promises certain advantages.

With the aid of the 21-foot concave-grating spectrograph and the 150-foot reflecting telescope of the Solar Laboratory he has obtained 69 plates of disk and sunspot spectra covering the interval $\lambda 3100-11400$. Some 800 Å in the ultraviolet and 2500 Å in the infrared are thus added to the region of the spot spectrum available for study. The ultraviolet spectrograms show that the ultimate or penultimate lines of the heavy elements *Ag*, *Pd*, *Ru*, *Rh*, *Pb*, *Yb* II, *Cd*, and *Sn* are strengthened in spots, as are the bands of *OH* and *NH*. In the infrared the behavior of such light elements as *C*, *S*, and *P* is revealed for the first time. *Fe*, *Cr*, *Ni*, *Ca*, *O*, and other abundant elements display changes to be expected from the excitation potentials of the various multiplets. Hundreds of weak lines, often obviously part of a band, appear in the new spot spectrograms, and various new bands await identification.

Measurements of line displacements at the solar limb, made by Babcock in 1922-1923 with the Snow telescope and 30-foot plane-grating spectrograph, have been reviewed and prepared for publication in summarized form. The mean displacement of 230 lines between $\lambda 5100$ and $\lambda 6408$ observed at points 0.01R

(R =solar radius) in from the limb is 0.0054 A to the red. The displacement decreases at a nearly linear rate and becomes 0 at 0.58 R . The displacement of iron lines of high excitation potential is certainly less than that of lines of low excitation potential.

The photoelectric microphotometer developed at Mount Wilson for direct analysis of the solar spectrum has been used by Dunham at the University Observatory at Oxford in connection with the powerful prism spectrograph recently completed by Professor Plaskett. As a basis for comparison with Mount Wilson results obtained with gratings, the resolution of the prism spectrograph was measured photoelectrically with the aid of a very intense sodium lamp. The distribution of scattered light in the focal plane was derived by several methods, and in the sun itself the contours of the D lines and others near by were recorded both by the deflection method and by a null method involving the use of two photoelectric cells. The results have a bearing on the program for the photoelectric photometry of solar absorption lines.

A spot with an unusually large umbra, which appeared in November 1938, provided an excellent opportunity for an extension into the infrared of the map showing the magnetic behavior of the spot lines. Photographs by Richardson made at the 150-foot tower on Mount Wilson with a Nicol prism and quarter-wave plate carry the series of overlapping spectrograms now available out to $\lambda 9000$.

The intensity ratio of spot to disk was measured by Richardson for 13

stable spots on 25 days of excellent seeing in four different spectral regions selected for freedom from spectral lines. The results agree much better with a state of radiative equilibrium than with the adiabatic equilibrium commonly assumed to exist. Probably because of greater freedom from scattered light, the data indicate for the umbra an effective temperature of 4300° K, about 500° lower than that usually given.

SIXTY-FOOT TOWER TELESCOPE

The reconstruction of the 60-foot tower telescope, to which reference was made in last year's report, has been essentially completed. The outer tower and dome have been moved about four feet northward to provide for continuous observation of the sun throughout the summer days without changing the position of the coelostat. New mountings for the coelostat and second-flat mirrors have been installed. Two important improvements are a synchronous motor drive, designed by E. C. Nichols, the rate of which can be varied at will by the observer without climbing the tower or stopping the motor; and a photoelectric guiding device, designed by Dr. A. E. Whitford, which corrects automatically irregularities in the drive due to any cause. The spectrohelioscope can now be used for scanning the sun while photographs are being made with the spectroheliograph.

A grilled floor under the dome allows air to circulate around the mirrors and should improve seeing conditions. The photographic darkroom at the base of the tower is being placed under temperature control.

LUNAR AND PLANETARY INVESTIGATIONS

SURFACE FEATURES OF THE MOON

Dr. F. E. Wright, Chairman of the Committee on Study of the Surface Features of the Moon, photographed the

moon at the Newtonian focus of the 100-inch telescope at frequent intervals on July 1 to 24, 1938. On 16 nights the seeing was less than 2 on a scale of 10,

and at no time did it exceed 5. A few additional photographs were made July 29 to August 4, often when the seeing was 1 or less.

Preliminary study of enlargements of several hundred of these negatives by Miss Helen Wright at Vassar College shows that in spite of the handicap of poor seeing the material can be used to measure the slopes of certain lunar features by the method of grazing incidence. The data thus obtained permit the construction of rough topographic maps of these features. In addition, examination of numerous stereoscopic pairs of negatives with adequate stereoscopic power has revealed physiographic features not apparent on the single negatives. In preparing the series of photographic maps showing the moon at different phases, the best of these negatives will be transformed to the plane of mean libration.

Photoelectric measurements of the percentage amount of polarized light received from selected regions of the moon's surface have been continued and supplemented by measurements of terrestrial materials illuminated under similar conditions of varying phase angle.

Some experiments by Pettit suggest that the method of superposition may be used to increase the visibility of details on lunar photographs. When a negative is matched with a contact positive so adjusted that corresponding details are not quite coincident the picture appears in cameo-like relief. Trials with some of the best negatives made at the 100-inch telescope by Pease about 20 years ago showed an enhancement of features not easily seen on either the negative or the positive.

OCCULTATION OF STARS BY THE MOON

The occultation of two stars was observed photoelectrically by Whitford with the aid of a recording system sensi-

tive to less than 0.002 second. The variation in light as the star passed behind the dark limb of the moon followed closely that calculated from diffraction theory, with the limb treated as a straight edge and the star as a point source. The distortion of the diffraction pattern produced by a star 0".005 or more in diameter, several of which are within the occultation zone, should be measurable and thus provide a determination of the diameter itself.

SATELLITES OF JUPITER

A photographic search by Nicholson with the 100-inch reflector resulted in the discovery of two new satellites of Jupiter, thus increasing the number known from nine to eleven. In accordance with established custom these satellites will be known as J X and J XI. J X, discovered on July 6, revolves about Jupiter in a period of about 260 days. Its photographic magnitude at mean opposition is 18.8 and its probable diameter 15.5 miles. J XI, discovered on July 30, revolves about Jupiter in about 700 days. Its photographic magnitude is 18.4 and its probable diameter 19.5 miles.

The search covered all the area around Jupiter within which satellites might be found and should have been complete to a limit at least a half-magnitude fainter than those discovered. All the other faint satellites of Jupiter were observed and accurate positions derived from the photographs. About fifty asteroids were found during the search, some of which moved so nearly like satellites that it was necessary to follow them for several days to be certain that they were really asteroids.

MOTION-PICTURE CONTROL

A simplified control for exposures with a motion-picture camera has been devised by Pettit which provides for a wide range in the ratio of exposure time to

dark time. A synchronous motor is used and the timing of individual exposures is obtained from the instants of begin-

ning and end of the series. The device has been used for planetary photography and can be adapted to solar work.

MISCELLANEOUS STELLAR INVESTIGATIONS

TRIGONOMETRIC PARALLAXES AND PROPER MOTIONS

In his search for stars of low luminosity van Maanen has found among the stars on his parallax program 14 which have photographic absolute magnitudes (PgM) fainter than +10, 3 of which are fainter than +15. The parallax derived for Wolf 457 is $0''.079$, whence PgM is +15.1. Since the spectrum, according to Kuiper, is of type O, the star appears to be a white dwarf, the faintest known. The preliminary parallax for Wolf 424 (separation $1''$) is $0''.212 \pm 0''.024$; for each component, therefore, $PgM = 16.1$.

Lalande 21258 has been found to have a physical companion $19''$ south and $20''$ east, the common proper motion being $4''.5$ annually. The apparent photographic magnitude (Pgm) of the companion, from two dozen Harvard and Mount Wilson plates, is about 16.0. The parallax of Lalande 21258 is $0''.173$, whence for the companion, $PgM = +17.2$. The most remarkable thing, however, is that the companion seems to be variable. Two exposures separated by an interval of 36 minutes, made by van Maanen on May 11, 1939, and measured by Baade, give $Pgm = 14.23$ and 14.53 , respectively. For data on the spectrum of the companion see page 21.

SPACE DENSITY OF STARS NEAR THE SUN

From the present accumulation of data, which indicates a great scarcity of large proper motions among apparently faint stars, van Maanen finds a revised value of 0.13 stars per cubic parsec for the mean space density near the sun. On this basis the number of stars within 5 parsecs of the sun would be 69, of

which 35 are known (companions of double stars excluded). Spectral types are available for 32 of the 35, two-thirds of which are M's. Among the 21 known stars having PgM greater than +10, there are 17 M's, 1 F, and 3 of unknown type. The color index of stars near the maximum of the frequency-curve of absolute magnitudes is therefore 1.5 to 2.0 mags. The visual absolute magnitude +12.7 found by van Maanen for maximum frequency therefore agrees well with Luyten's value $PgM = +14.7$ derived from proper motions in the southern hemisphere.

FAINT PHOTOMETRIC STANDARDS

To provide very faint standards of brightness for use in studies of extragalactic nebulae, Baade, as already reported, has extended the scale of the *Mount Wilson Catalogue* for Selected Area 68 to photographic magnitude 21. Similar extensions for Areas 57 and 61 are well under way. The 100-inch telescope and zero corrector are used, and the exposures are made through a platinum half-filter.

Baade has also established sequences to photographic magnitude 18.0 for the supernova in NGC 4636 and to 20.2 for the anonymous nebula at $2^h 34^m 0^s$, $+34^\circ 2'$. In order to strengthen the brighter part of the comparison-star sequence for the extragalactic system IC 1613, he has made six additional intercomparisons with the standards in Selected Area 68.

PHOTOMETRIC EXTENSION OF THE POLAR SEQUENCE

The investigation of the magnitudes and colors of about 2000 stars north of

+80°, undertaken by Seares and Miss Joyner jointly with Dr. Ross of the Yerkes Observatory, is finished except for the formation of the final mean photovisual magnitudes and some minor adjustments of the photographic means arising from last-minute revisions of color indices.

COLOR EXCESS IN THE POLAR REGION

The mean color excess of about 0.1 mag. for the brighter stars near the North Pole, found by Seares and confirmed by Stebbins and others, can be investigated in detail as soon as the final color indices for stars north of 80° are finished. Meanwhile, provisional colors, combined with spectral types by Schwassmann and by Petersson, have given values of the color excess for several hundred stars down to a limiting photographic magnitude of 11.5. The general result is a selectively absorbing cloud, 300 or 400 parsecs thick, with its nearer edge at a distance of only 50 to 100 parsecs, covering the greater part, at least, of the region north of 80° declination. For stars beyond the cloud, out to the limit of about 1000 parsecs, the mean color excess seems to be constant for any field, but ranges from 0.2 to 0.4 mag. in different fields. This cloud is not to be confused with the one discovered by Shapley and Miss Jones from star counts, which is of much smaller angular area, involves only very faint stars, and apparently is at a much greater distance.

COLORS OF B- AND A-TYPE STARS

The catalogue of photoelectric colors of 1332 B-type stars by Stebbins and Whitford is ready for the printer. The investigation shows that the correlation of color excess with the intensity of interstellar lines is as close as that between interstellar lines in the same star. In other words, the dark interstellar mate-

rial which produces space reddening is closely connected with the interstellar gases.

The colors of the B stars also show that several brilliant regions of the Milky Way would appear twice as bright as they do could they be seen in the clear. The selective absorption is so irregular and spotted in its distribution, however, that it is difficult to believe that the coefficient of absorption remains constant over any large volume of space. The study is being continued by measures of the colors of Cepheid variables, stars of known luminosity situated at great distances.

The colors of over 100 A-type stars situated near the poles of the galaxy have also been observed. These data will give a measure of space absorption in the vicinity of the sun. The precise spectral classifications required for the fainter stars are being made by Joy and others of the spectroscopic department.

For use in determining the law of selective absorption, a new photoelectric spectrophotometer has been constructed, which can be used in both the infrared and the ultraviolet. Preliminary measures indicate a variation in the absorption proportional to $1/\lambda$, in agreement with some earlier observations.

ABSOLUTE MAGNITUDES OF F, G, AND K STARS

Strömberg has continued his statistical work relating to the systematic and accidental errors in the spectroscopic absolute magnitudes of dwarf stars of spectral types F, G, and early K. Using a neutral method of grouping and trigonometric parallaxes to determine the mean absolute magnitudes, he finds nonlinear impartial relation lines and regression lines, and, further, that the dispersions in the spectroscopic absolute magnitudes have been underestimated. After systematic corrections have been applied, he

finds for all three classes of stars a mean error of 0.5 to 0.6 mag. This value is considerably smaller than that derived by Russell and Miss Moore from an analysis based on the assumption of linear correlations.

In the course of this investigation Strömberg has determined the correlation function for two variables x and y , each a sum of n independent variables such that the component elements of x and y are mutually correlated. The new func-

adopted for the rotational constant A ; and A for the Cepheids, at least, is correlated with the absorption constant a . General considerations indicate that for Cepheids A can scarcely be less than 17.0 km/sec kpc and for N-type stars it can hardly be greater. The corresponding a is 0.5 mag/kpc. The results, corrected for absorption, are in the accompanying table. The effect on the final means of other reasonable assumptions for A does not exceed 0.1 or 0.2 mag.

Class	Absorption const. a	M_{π}	M_r	M
RR Lyrae	0	+0.2	-0.8*	-0.2 pg.
δ Cephei	0.5 pg.	-1.8	-2.0	-1.9 pg.
N	0.2 vis.	-1.7	-1.8	-1.7 vis.
R	0	-0.2	-0.6	-0.4 vis.
c	0.3 vis.	-3.6	-4.9	-4.3 vis.

*Half weight.

tion is identical in form with the ordinary correlation function, and its coefficient of correlation is a simple function of the partial correlation coefficients and the partial dispersions.

MEAN ABSOLUTE MAGNITUDES OF SPECIAL CLASSES OF STARS

R. E. Wilson has determined by two independent methods the mean absolute magnitudes (M) of the RR Lyrae and δ Cephei variables, the N- and R-type stars, and the very luminous c stars: first, by a comparison of the parallactic and peculiar motions derived separately from radial velocities and proper motions (giving M_{π}); and second, by a combination of the constant of galactic rotation with the rotational factors derived from the radial velocities alone (giving M_r). Since the troublesome correction for dispersion in distance appears with opposite signs in M_{π} and M_r , any uncertainty in its value is largely eliminated from the final mean M .

The value of the mean distance \bar{r} , and hence of M_r , found from the rotational factor $\bar{r}A$ naturally depends on the value

The results for the c stars show a marked dependence on spectral type. For groups having practically the same mean apparent magnitude, the values of M , corrected for absorption and for dispersion in distance, are:

Type	M vis.
B	-5.9
A	-5.0
F	-4.4
G	-3.5
K	-3.0

ZERO-POINT CORRECTION OF PHOTOGRAPHIC PERIOD-LUMINOSITY RELATION

With Joy's values of the rotation and absorption constants, $A=20.9$ km/sec kpc and $a=0.85$ mag/kpc, respectively, R. E. Wilson finds from both RR Lyrae and δ Cephei variables a zero correction to the zero point of Shapley's period-luminosity relation. The corrections from M_{π} and M_r for the Cepheids, however, are -0.4 and +0.4, a difference quite inconsistent with the precision of the data. A much better agreement follows from $A=17.0$ km/sec kpc and $a=$

0.50 mag/kpc, as shown in the accompanying table. It seems unlikely, therefore, that the correction greatly exceeds a tenth of a magnitude.

	CORRECTION FROM		MEAN
	M_{π}	M_r	
RR Lyrae variables	+0.18	-0.82*	-0.15
δ Cephei variables..	-0.12	-0.14	-0.13

*Half weight.

The calculated values of mean M for data grouped according to $\log P$ (P = period of variation) confirm the slope of the curve, as shown in the accompanying table.

$\log P$	Computed M	Curve M
-0.32.....	0.0	0.0
+0.66.....	-1.2	-1.2
+0.88.....	-1.9	-1.7
+1.26.....	-2.3	-2.3

PHOTOELECTRIC PHOTOMETRY OF STELLAR IMAGES

With a photoelectric cell and electronic amplifier Dunham has measured the distribution of light within stellar images as formed at the coudé focus of the 100-inch telescope. The image was moved across an analyzing pinhole 0".3 in

diameter by means of a tilting parallel plate, the varying transmission being automatically recorded as a distribution-curve. In a second method the transmission was measured for each of 14 apertures ranging from 0".3 to 40" diameter, centered on the image in succession. With seeing 4, the intensity at 1" from the center is one-half the maximum. With seeing 2, the half value occurs at 2" distance. In the worst seeing encountered, 10 per cent of the light failed to pass a 40" aperture.

PHOTOGRAPHY AT THE PRIMARY FOCUS OF THE 60-INCH REFLECTOR

Direct photographs at the primary focus of the 60-inch reflector were made by Hubble on four nights in order to compare the gain in performance over the Newtonian focus with the loss in convenience of operation. For exposures of less than 30 minutes the tests favor the Newtonian focus, but for long exposures the primary focus is more efficient, presumably because of a reduction in scattered light and sky fog and because of the greater stability of a single mirror surface as compared with a combination of surfaces. The tests will be continued in order to determine the actual gain in limiting magnitude.

STELLAR SPECTROSCOPY

The principal addition to the stellar spectroscopic equipment during the year has been a Schmidt camera with a focal length of 114 inches for use in the spectrograph at the coudé focus of the 100-inch telescope. No correcting plate is employed and the 36-inch spherical mirror, loaned to the Observatory by the Fund for Astrophysical Research, is supported by a framework attached to the heavy I-beams forming the main frame of the spectrograph. A plate 20 inches long is used and the definition is excellent. Constancy of focus for all regions of the

spectrum and a complete absence of glass in the spectrograph train give this form of the instrument marked advantages over that with a camera lens used previously. The spectrograph is now provided with three Schmidt cameras with focal lengths of 32, 73, and 114 inches, all utilizing the same grating and collimating mirror.

A special type of Schmidt camera for use on very faint objects with the nebular spectrograph has been completed and tested. It consists of a block of highly transparent glass, one end of which is

figured to a convex spherical curve and aluminized. The other end of the glass block is made plane; to it is cemented a thin glass plate which supports the small photographic plate. The thickness of this plate is determined by the focal length of the camera and is fixed once for all. The photographic plate rests on the glass plate, making contact through a film of oil. The correcting plate is placed between the prisms and the camera and has a clear aperture of 2 inches, while that of the concave mirror of the glass block is 3.1 inches. The combination works at a focal ratio of $F/0.67$ and gives good definition.

During the year 1304 stellar spectrograms have been obtained with the various instruments. Of these 323 were taken at the coude focus of the 100-inch telescope and the remainder at the Cassegrain focus of the two large reflectors. The stars observed include many variables of different classes; numerous O and B stars investigated for interstellar lines of calcium and sodium; stars of types R, N, and S, more especially those of large velocity; stars in the Orion Nebula with spectra showing nebular *He* absorption; B- and A-type stars with c characteristics; numerous spectroscopic binaries and stars of composite spectra; faint stars of large proper motion; stars in the Selected Areas; and several hundred stars of types G5 to K5 observed in the violet region for spectroscopic criteria of absolute magnitude. Physical studies of the spectra of the brighter stars and measurements of line-intensities have been continued with the high-dispersion coude spectrograph.

RADIAL VELOCITIES

From 10 well-determined velocity-curves of RR Lyrae variables Joy has found a mean velocity range of 68 km/sec, a value much larger than that for Cepheid variables. With the aid of this result he has obtained from the data now

available approximate normal velocities for 67 RR Lyrae stars. For half these stars, which show little or no galactic concentration, the normal velocity exceeds 75 km/sec; but the scatter is large and the group motion relative to the sun is probably also large. The normal velocities are of little value in determining the constants of galactic motion.

Joy has also determined the mean radial velocities of the RV Tauri variables and of the irregular M-type variables without bright lines as 49.7 and 26.2 km/sec, respectively. These average velocities are taken without regard to sign and are corrected for a solar motion of 20 km/sec. The stars show little or no galactic concentration.

Merrill has measured the radial velocities of 10 additional stars of types Me and Se in continuation of his program on long-period variables. These stars are faint and can be observed only within a few weeks of maximum of light. Additional observations of stars previously investigated are providing further material for a study of the relative displacements of dark and bright lines.

Sanford has completed measurements of the radial velocities of a number of N- and R-type stars and has also carried on observations of the stars selected by the International Astronomical Union as standards for velocity. Stars in Kapteyn's Selected Areas have been under regular observation during the year by Strömberg and Christie.

A few spectroscopic binaries, either of long period or with a suspected variation of the velocity of center of mass, are under investigation by Sanford. Sanford has also reobserved several spectroscopic binaries of early type with previously determined orbits to check the periods. O. C. Wilson has found the Wolf-Rayet star HD 193576 to be almost certainly a spectroscopic binary with double lines and a large velocity range.

Christie has redetermined the mini-

imum masses of the two components of the giant eclipsing star ζ Aurigae from measures of 20 spectrograms extending well into the ultraviolet. The results confirm satisfactorily the values of 8.3 and 15.3 times the sun's mass for the B- and K-type components, respectively, previously published by Christie and Wilson.

The high-dispersion coudé spectrograms of α Boötis are being utilized by Adams for an accurate determination of the radial velocity of the star and for a derivation of the solar parallax. A preliminary solution from 19 spectrograms gives for the parallax $8''.805 \pm 0''.013$.

Two spectrograms of the faint companion to Lalande 21258, discovered by van Maanen, were obtained by Humason on April 16 and May 22, 1939. Although the star had been two magnitudes brighter than normal on May 11, both plates showed the spectrum to be of type M5e with $H\beta$, $H\gamma$, $H\delta$, $H\zeta$, and H and K bright. The radial velocity was found to be in substantial agreement with that of the brighter star.

The well-known abnormalities of the H and K lines of calcium in the spectrum of the sun and of numerous stars led Adams and Joy to investigate these lines in the spectra of the brighter Cepheid variables. On strongly exposed spectrograms these lines narrow down to well-defined cores which can be measured satisfactorily. The first star investigated was ζ Geminorum, and marked differences between radial velocities given by H and K and by the normal stellar lines were soon apparent. A series of spectrograms taken throughout the period of light-variation gave a velocity-curve which could then be compared with the normal curve. At maximum of light the curve for H and K is about 12 km/sec above that for the normal stellar lines. The H-and-K curve falls while the normal curve rises, the crossing point being 1.3 days after the normal minimum velocity. At minimum velocity for H and

K the deviation from the velocity for the normal lines amounts to 22 km/sec. The H-and-K curve then rises very rapidly, crossing the normal curve about 0.4 day after maximum positive velocity for the normal lines.

The two curves differ considerably in form and cannot be superposed through a change in phase. Moreover, the total range in velocity given by H and K is about 38 km/sec as compared with 29 km/sec for the normal lines. Emission lines on the sides of the strong absorption cores of H and K appear at the time of the rapid rise from maximum negative to maximum positive velocity.

Observations of the Cepheid η Aquilae show similar differences, and the velocity-curve is now being determined.

GALACTIC ROTATION

Joy has used the radial velocities of 156 Cepheid variables in a calculation of some of the constants of the galaxy. The distances of the stars were computed from the period-luminosity relationship, with the visual magnitudes corrected for a general space absorption of 0.85 mag. per 1000 parsecs. The rotation effect for a distance of 1000 parsecs is found to be 20.9 km/sec, and the distance to the center of rotation 10,000 parsecs in longitude $325^\circ 3$. The use of Bottlinger's formula gives for the circular orbital velocity of the sun 296 km/sec and a period of revolution of 207,000,000 years. After elimination of a solar motion of 20 km/sec and the circular rotational effect, the mean radial velocity of the Cepheids is found to be 10.8 km/sec.

PHYSICAL STUDIES OF SPECTRA

Irregularities in the intensity, structure, and displacements of the ultraviolet bright lines of Me variables have been investigated by Merrill. The duplicity of H_t has been observed in some

of the brighter variables. Merrill is also studying the band spectra of these stars in the yellow and red regions.

The spectra of cB and cA stars show marked peculiarities in the structure of the D3 and $H\alpha$ lines which are being studied by Merrill. He has identified some 25 lines of neutral neon in the yellow and red portions of the spectrum of ν Sagittarii, a star showing these lines more prominently than any other star so far observed.

Joy has made a spectral investigation of irregular variable stars with fluctuations of intermediate length. With few exceptions they fall into three main classes: SS Cygni stars, whose spectra are practically devoid of lines at maximum of light and show broad emission bands of hydrogen at minimum; RV Tauri stars, which are of type F or G at maximum of light, often show titanium oxide bands at minimum, and frequently sharp emission lines of hydrogen as their light increases; and irregular M-type variables without bright lines, whose spectral types are concentrated about M6. Of the 78 stars of this last class which have been observed, only one shows a spectrum earlier than M4. High-dispersion spectra of α Ceti have been used by Joy in a study of the structure of the emission lines.

O. C. Wilson has continued his observations of stars involved in the Orion Nebula which show nebular absorption lines. Measurements of the velocities given by these lines and of their intensities are essentially complete.

Many B-type stars with emission lines have been discovered on objective-prism photographs taken by William C. Miller and classified by Merrill and Miss Burwell. The interesting Be stars BD +11°4673 and HD 142983 have been observed extensively by Merrill and Sanford. The Be "companion" spectrum in the remarkable system of R Aquarii is

now very faint and the nebular lines are conspicuous.

Several previously unrecorded stars of types N and S have been found on the objective-prism photographs, and a Wolf-Rayet star has been discovered with a remarkably high velocity. Most of these stars have been further studied by Sanford with a slit spectrograph.

High-dispersion spectra of the red supergiant stars, investigated by Adams, show that the doubling of numerous lines first discovered in the spectrum of α Orionis is also characteristic of the other stars. The relative intensities, however, and the separation of the components differ markedly. A partial photometric study of these spectra has been completed by Lyman Spitzer, Jr. The hypothesis that these effects are due to extensive convection currents in the stellar atmospheres seems to be the most satisfactory of any so far suggested.

The spectra of 14 white dwarfs brighter than magnitude 15 have been photographed by Minkowski as the basis for a study of this interesting class of objects. Relatively low dispersion is used, but the spectra are considerably widened.

The spectrum of α Lyrae, photographed with the highest dispersion of the coude spectrograph by Adams, shows lines which are distinctly abnormal in contour and possibly double. The star is now under investigation.

Systematic determinations of line-intensities in representative bright stars have been continued by Dunham, assisted by Miss Carlson, principally with the 9-foot coude spectrograph. The new 114-inch Schmidt camera already described should be especially valuable for this work. A logarithmic-scale rastrum for calibration purposes will greatly simplify the reductions.

INTERSTELLAR LINES

Several investigations have dealt with the interstellar lines H and K of ionized

calcium and the D lines of neutral sodium in various types of stellar spectra. Of these the most extensive is the spectrophotometric study by Sanford and O. C. Wilson of the ratio K/H in stars of types B3 and earlier. The results indicate that K/H ranges from about 2.00 for the weakest lines to about 1.56 for the strongest. On the other hand, the ratio D2/D1 of sodium for the same stars ranges between only 2.0 and 1.2. Unless larger systematic errors are present in the measures than seem at all probable, a direct interpretation would lead to the surprising conclusion that small-scale turbulent motions of the interstellar calcium ions are of the order of three times those of the sodium atoms. All other evidence has indicated a complete mixture of these forms of the two elements in space.

A valuable by-product of this investigation is the determination from the absorption of the interstellar lines of a mean visual absolute magnitude of -2.8 for 6 Wolf-Rayet stars of the carbon sequence and of -2.1 for 12 stars of the nitrogen sequence.

Components of the D lines due to interstellar sodium, discovered by Sanford in the spectra of HD 137613 of type R0 and HD 189711 of type Nb, have been measured photometrically and yield visual absolute magnitudes for these stars of -0.6 and -2.1 , respectively. These values are in close agreement with those determined from proper motions and radial velocities.

In the region of the Orion Nebula Sanford has found 5 additional stars showing double lines of interstellar calcium. For the 13 stars in this region the violet and the red components give mean radial velocities of $+2.5$ and $+25.5$ km/sec, respectively. The mean from the stellar lines is $+25.7$ km/sec. Although this value agrees closely with that from the red component, the narrowness and sharpness of this component as com-

pared with any of the stellar lines makes it improbable that it is of stellar origin. The mean radial velocity of the Orion Nebula according to Campbell and Moore is $+17.7$ km/sec.

The spectra of the three B-type stars ζ Ophiuchi, α Persei, and 55 Cygni have been photographed by Adams with the highest dispersion of the coudé spectrograph and show the three unidentified interstellar lines at $\lambda 3957$, 4232 , and 4300 with exceptional clearness. Accurate determinations of their wave lengths have been made from these spectrograms. The relative intensities of the three lines in these spectra make it improbable that they are due to the same element. A faint line, almost certainly of interstellar origin, appears in the spectrum of ζ Ophiuchi at $\lambda 3874.6$.

BOWEN'S IMAGE SLICER

A device developed by Dr. I. S. Bowen of the California Institute of Technology is one of the most promising of recent optical aids to the study of stellar spectra. For spectrographs used with large telescopes, especially if the seeing is poor, the diameter of the stellar image is several times greater than the width of the slit. The image slicer intercepts the light in narrow outlying strips of the image, which otherwise would be lost, and reflects it into the slit alongside that transmitted directly from the central strip. The wide spectral image thus produced is compressed by a cylindrical lens to obtain the maximum practicable intensity. Photoelectric measurements by Dunham show that the image slicer increases the light entering the spectrograph by a factor of from 2 to 6 according to the seeing.

The device is especially well adapted for use with Schmidt cameras or with the spherical mirror of the new coudé spectrograph. It is then advantageous to make the cylindrical lens of lucite, which

can be bent into parallelism with the spherical focal surface. Under these conditions all the incident rays are perpendicular to the longitudinal axis of the lens and the aberrations are thus held at a minimum.

THE MATERIAL OF INTERSTELLAR SPACE

A revised estimate by Dunham of the abundance of electrons and atoms in interstellar space has given the values shown in the accompanying table.

	Electrons	H	Na	K	Ca	Ti
Without absorption.....	14×10^6	15×10^6	110	15.5	6.4	0.07
With absorption.....	7×10^6	8×10^6	103	5.0	3.1	0.02

The calculation is based, first, on the relative numbers of neutral and singly ionized atoms of calcium and second, on the ionization produced by interstellar radiation. The ratio $Ca\ I/Ca\ II$ was derived from measures of the faint interstellar line $\lambda 4227$ in the spectrum of χ^2 Orionis, provisionally identified as due to neutral calcium, while the distribution of interstellar radiation was obtained by integrating the light of all the stars down to the twenty-first magnitude, the result being expressed in terms of 10 black-body sources of different temperatures,

having different dilution factors. The resulting electron density, combined with measured intensities of the other interstellar lines, gives the abundance of the different elements. That of hydrogen, which is not observed directly, is inferred as the only reasonable source for the required number of electrons. The results, which refer specifically to the direction of χ^2 Orionis, are only roughly approximate, owing to uncertainties in the integration of starlight, and to the fact that the ionization equation used is not strictly

applicable to interstellar space. The latter circumstance may reduce the electron density and the abundance of hydrogen by a factor of 10, but should not greatly affect the results for the heavier elements.

The second series of values is for an absorption assumed to vary at $1/\lambda$, based on Stebbins' measures of B stars. The fact that the results for sodium and calcium are higher than the averages found by Merrill, Sanford, and O. C. Wilson may, to some extent at least, represent the influence of local conditions in the direction of χ^2 Orionis.

GALACTIC NEBULAE AND GLOBULAR CLUSTERS

COLOR PHOTOGRAPHY OF NEBULAE AND CLUSTERS

The program of photography with light from the red region of the spectrum has been continued by Baade. The objects studied include several star clusters in the Sagittarius region, which had been discovered on red-sensitive films exposed with the 18-inch Schmidt telescope on Palomar Mountain, and a number of extragalactic systems and clusters of nebulae.

In another direction, a series of ex-

perimental color photographs of star clusters and nebulae has been made by Duncan in order to explore the possible applications of Kodachrome film. Although the relatively low threshold sensitivity of the film restricts its usefulness to the brighter objects, the preliminary results appear to justify further investigations.

THE CRAB NEBULA

The fact that the Crab Nebula is probably the remnant of a supernova that

appeared in A.D. 1054 has led Baade and Minkowski to undertake a complete photometric and spectroscopic investigation of its characteristics. The question as to which of the two components of the central star, both of photographic magnitude 16.6, is the exciting source for the nebula seems now to have been answered. Photographs on red-sensitive plates made in 1937 favored the south preceding component by showing it to be the bluer of the two. The single spectrogram thus far obtained confirms the difference in color but leaves the spectral types still somewhat in doubt.

To investigate a possible absorption within the nebula, a series of photographs covering various intervals of wave length has been made. The photographs in red light show a wealth of sharp detail, especially in the outer filaments, which apparently are very strong in $H\alpha$ radiation. These red photographs should be especially valuable for future measurements of the expansion of the nebula.

Meanwhile, Duncan has remeasured the expansion on blue photographs separated by an interval of 29 years. On the assumption of uniform expansion, the measures indicate that the initial out-

burst occurred nearly 800 years ago, at a point about $20''$ east of the northern component of the central star. The nebula appears to be moving west at a rate of $1''.9$ to $3''.7$ per century, depending on the method of evaluation. The central star is evidently an optical double because the northern component shows no appreciable motion, while the southern component, presumably the exciting source for the nebula, has a proper motion of $1''.9$ per century toward the west.

MAGNITUDES OF GLOBULAR CLUSTERS

The reduction and discussion of the integrated photographic magnitudes of 68 globular clusters by Christie have been finished and the manuscript is ready for the printer. As far as a comparison is possible, there is no disagreement in scale with the photoelectric measures of Stebbins and Whitford. The average error of a single determination is ± 0.11 mag. The absolute magnitudes of the 39 clusters for which distance moduli are available range from -4.7 to -9.5 . Maximum frequency occurs at -7.6 . The luminosity-curve suggests the possibility of a secondary maximum between -5 and -6 .

EXTRAGALACTIC NEBULAE

CONFERENCE ON THE STRUCTURE OF NEBULAE

An important event of the year was an informal conference on the structure and dynamics of nebulae, held at Pasadena in June 1939 and attended by Dr. Bertil Lindblad (Stockholm), Dr. N. U. Mayall (Lick), and Dr. J. H. Oort (Leiden), in addition to members of the research staffs of the Observatory and the California Institute of Technology. The joint discussions by observers and theoretical investigators furnished a critical examination of current working hypotheses, a notable clarification of

controversial problems, and a tentative evaluation of possible new fields of investigation.

A survey of observational data suggested that the collections of direct photographs already available are sufficient for a detailed study of structural forms. On the other hand, dynamical investigations are seriously limited by the paucity of spectrographic measures of internal motions, including rotational patterns at various stages in the sequence of classification.

Especial emphasis was placed on the desirability of undertaking a study of

large-scale spectra of nebulae—an almost unexplored field of major importance. Because of recent improvements in spectrographs and photographic emulsions, the project is now considered to be feasible and the necessary equipment is being assembled at Mount Wilson.

THE SEQUENCE OF CLASSIFICATION

Considerable progress has been made by Hubble in the study of structural forms of nebulae. The data include a complete, homogeneous collection of photographs of the 800 Shapley-Ames nebulae brighter than the thirteenth magnitude and north of Dec. = -30° , the nebulae to the twelfth magnitude between Dec. = -30° and -43° , and, in addition, about 1500 of the fainter Dreyer nebulae scattered over the sky.

The validity of the current sequence of classification has been fully confirmed, and various gaps have been filled by hitherto unrecognized forms. Progression throughout the entire sequence now appears to be smooth and continuous. Results derived during the past year include detailed, quantitative descriptions of the transitional stage between elliptical nebulae and fully developed, early-type spirals, of the early spirals, and of the barred spirals as a group. It is probably significant for the theoretical interpretation of spirals that the spiral structure first develops within the nebula, apparently by the segregation of material already in place rather than by the ejection of material into regions previously unoccupied.

NEW STELLAR SYSTEMS IN SCULPTOR AND FORNAX

These two faint systems, recently reported by Dr. Shapley of the Harvard Observatory, are under investigation by Baade and Hubble with the 100-inch telescope. Although the southern declinations of 34° and 35° are an obstacle,

provisional results already indicate that both objects are dwarf systems at distances of roughly 300,000 (Sculptor) and 600,000 (Fornax) light-years and thus are members of the local group of extragalactic nebulae to which our own stellar system belongs. This group now consists of 11 recognized members, 5 of which are dwarfs. Cepheid variables have been found in Sculptor, and two globular clusters in Fornax; but neither system shows a nucleus or any supergiant stars or any trace of diffuse nebulosity.

SURVEY OF NEBULAE IN LOW GALACTIC LATITUDES

A supplementary survey in low galactic latitudes has been undertaken by Baade and Hubble for the purposes of more precisely delimiting the zone of avoidance of nebulae and defining regions of exceptional transparency where galactic structure may be studied with the aid of some information concerning the total obscuration. The program includes fields at latitudes 5° , 7.5° , and 10° on each side of the equator, at each 5° of longitude from 320° to 220° . Blue photographs (E 40) are already available for latitudes 5° and 10° , spaced 10° in longitude. For the additional fields, red plates (Eastman $H\alpha$ Specials) are being used in order to investigate possible effects of heavy selective absorption. The thirty plates already assembled tend to confirm the general pattern of the zone of avoidance as previously outlined in the belt $\lambda=0^\circ$ to 80° , and furnish no evidence of appreciable selective absorption along the fringe of the zone.

LIGHT-CURVES OF SUPERNOVAE

The supernovae discovered at Palomar Mountain by Dr. Fritz Zwicky of the California Institute of Technology have been observed regularly by Baade with the 60-inch and 100-inch reflectors on Mount Wilson in order that their respec-

tive light-curves might be determined as completely as possible. Measures of supernova NGC 1003 were ended by unfavorable weather conditions on November 25, 1938. The photographic magnitude of the star was then 19.7. Supernova IC 4182, discovered in August 1937, was last observed in May 1939, when its brightness was close to 21. The most complete light-curve thus far obtained is that for supernova NGC 4636, which was discovered more than a week before the maximum and thus defines the form of the maximum itself. The light-curves of these three supernovae are so closely similar during the 100 days following their maxima that the individual deviations from the mean curve are of the order of only 0.1 to 0.2 mag.

SPECTRA OF SUPERNOVAE

Spectra of the three supernovae discovered during the year have been observed by Minkowski. The supernovae in Pisces ($2^h 33^m 7^s$; $+34^\circ 11'$) and in NGC 4621 are each represented by a single spectrogram, taken about six weeks and three weeks, respectively, after maximum. For supernova NGC 4636, eleven spectrograms were obtained by Minkowski and Humason during the interval from a week before to about seven weeks after maximum.

The first of the series, representing the earliest premaximum stage hitherto observed, already shows the typical supernova spectrum. Supernovae, unlike ordinary novae, therefore apparently undergo no significant changes in spectral characteristics near maximum. Initially the spectrum appears to consist of very wide bands which diminish gradually until about two weeks after maximum. At the same time, the bands in the blue region shift gradually toward the red by about 150 Å. This red shift may, however, be due to the decrease in band width. The phenomena are not inconsistent with the

assumption of a decreasing outward velocity in a thin expanding atmosphere such that the back side of the emitting layer is hidden by the star. Thereafter, however, the band width apparently remains constant, while the red shift continues to increase to a total of about 250 Å at eleven months after maximum. The difficulties of interpretation therefore still remain.

The later observations of these three supernovae confirm the lack of essential differences in the spectra of different supernovae. No satisfactory identification for any of the details in the spectrum can yet be offered. Attempts at interpretation meet serious obstacles in the relative intensities of the red and the blue regions, in the absence of bands in the ultraviolet, and in the progressive red shift of the blue bands, especially in the later stage of development.

OLD SUPERNOVAE

During routine comparisons of recent with old photographs, a supernova was found by Hubble on two plates of NGC 4038, made by Duncan on March 7 and April 5, 1921. A second old supernova was found by Hubble and Zwicky on a plate of NGC 3184 made by Duncan on April 6, 1921. The two objects raise the number of known supernovae to 30.

RADIAL AND ROTATIONAL VELOCITIES OF NEBULAE

Humason has obtained spectrograms of 48 hitherto unobserved extragalactic nebulae. The majority of these nebulae are isolated systems, but the list also includes members of the clusters in Virgo and in Coma and of the large groups in Pisces and in Ursa Major.

He has also determined the spectrographic rotation of NGC 2685 ($P_g m = 12.5$; main body, 2.0×0.5 ; type, according to Hubble, S0 pec.). Over the measured range of $20''$ on each side of the

nucleus the velocity varies linearly with the distance from the nucleus. This nebula is the faintest of the five whose rotations have been determined. An investigation of a sixth nebula, NGC 2403, based on spectra of isolated emission patches, is in progress.

MOTION OF THE GALACTIC SYSTEM RELATIVE TO THE NEBULAE

An indication of the motion of the galactic system relative to the nebulae has been obtained by Hubble from radial velocities of nebulae outside the

local group but at distances less than 2,000,000 parsecs (red shifts less than 1000 km/sec). The results suggest a motion of the order of 150 km/sec in the general direction of the north galactic pole. A relatively small velocity and a high positive latitude for the apex appear to be definitely indicated, although precise numerical values cannot be derived from the data now available. A by-product of the investigation is the suggestion that the velocity-distance relation may not operate within the local group.

LABORATORY INVESTIGATIONS

SPECTRA OF RARE EARTHS

The temperature classification of 3950 lines of neutral and singly ionized europium has been finished by A. S. King. The classes have been checked by means of absorption spectra, and numerous lines appearing only on very strong spectrograms or as members of incomplete multiplets have been measured. A strong ultraviolet spectrum, belonging probably to *Eu* III, was found; and also, in the furnace spectrum, 17 bands of europium chloride, the heads of which were measured and the structure described.

A term analysis of the data for *Eu* I by Russell and King places in multiplets practically all the stronger arc lines and a majority of the weaker ones, 1156 in all. The spectral structure is very regular and in excellent agreement with Hund's theory. Most of the strong lines arise from terms of multiplicities 10, 8, and 6. The lowest level is $f^7s^2\ ^6S^0$. All the terms arising from the added electrons $6s7s$, $6s8s$, $6s5d$, $6s6d$, $6s6p$, $6s7p$, and $5d6p$ have been identified, and some from $6s7d$, $6s5f$, $6s6f$, $(5d)^2$, and $(6p)^2$. Numerous additional energy levels probably arise from the configurations f^6d^2 , f^6d^2s . In all, 272 levels were fitted into the analysis. For an element of high atomic number, *Eu* I displays an unusual degree

of regularity in the line-intensities of its multiplets. Its excitation potential was found to be 5.64 volts.

The very rich gadolinium spectrum, structurally quite different from that of europium, is being examined by A. S. King from $\lambda 2500$ to $\lambda 10000$. Many new spectrograms have been made, and the neutral and singly ionized lines have been segregated. Wave-length measurements, which are yielding many new lines, are well advanced. Examination of the furnace spectrograms and the temperature classification will complete the data required for an analysis of both *Gd* I and *Gd* II spectra and probably lead to a considerable increase in the solar identifications of the element.

Spectrograms of the rare element scandium are also being made, with a more abundant use of the element than has been possible before. The data obtained should thus be comparable with those for other elements of astrophysical importance.

MEASUREMENT OF ABSOLUTE *f*-VALUES

In collaboration with Professor D. C. Stockbarger, of the Massachusetts Institute of Technology, R. B. King has constructed a special furnace to aid in the determination of absolute *f*-values of

spectral lines of astrophysical interest. The important detail is accurate temperature control, in order that the absolute concentration of atoms in the furnace may be calculated. The observational data are the total absorptions of the lines as produced by the 15-foot concave-grating spectrograph. The work thus far includes tests of the accuracy of the method and a few preliminary results. For example, $Cd\ \lambda 3261$ gives the f -value 0.00185, in agreement with 0.0019 found by others by different methods; the resonance lines $Cu\ \lambda 3247, 3274$ give 0.62 and 0.33, respectively, of the order to be expected, since the lines are analogous to $Na\ D1$ and $D2$. $Tl\ \lambda 3776, 5350$ have also been investigated, and measurements of the strongest $Fe\ I$ lines are now being attempted.

RELATIVE f -VALUES FOR NEUTRAL NICKEL AND VANADIUM

The measurement of relative f -values by R. B. King has been continued. The absorption spectrum of $Ni\ I$ has been photographed from $\lambda 3000$ to $\lambda 3800$ at temperatures ranging from 1100° to $1300^\circ\ C$; and of $V\ I$ from $\lambda 3000$ to $\lambda 6700$ at temperatures from 1900° to $2500^\circ\ C$. The spectrograms are now being reduced. In addition, King and Minkowski have continued their study of the intensities of emission iron lines produced in the furnace by a method described in the 1935-1936 report.

ATLAS OF BAND SPECTRA

For reference purposes, R. B. King has begun a collection of photographs of band spectra, including arc and furnace spectrograms, chiefly of the oxides commonly occurring in the spectra of late-type stars.

HIGH-CURRENT VACUUM TUBES

Anderson has studied the behavior of the new commercial condenser units when

used with the high-current vacuum tube. Owing to the compactness of these condensers, their inductance is small compared with that of the ones previously employed. This results in a higher frequency of oscillation and consequently in increased current intensity. However, a very much higher internal resistance produces greater damping of the oscillations, which, in turn, tends to reduce the current intensity. What the net effect is has not yet been determined accurately. A preliminary attempt to study the energy-curve of the continuous spectrum of the vacuum tube by means of photographic photometry has been made, chiefly for the purpose of gaining experience in this type of work. The results are in fair agreement with those obtained in 1932 with the thermocouple.

RULING MACHINES

The large machine has been used by Babcock in experiments on the brightness of gratings ruled on heavy aluminium films evaporated on glass. Rulings of 900, 600, 480, 400, and 320 grooves per millimeter have been tested, some with a relationship between angles of incidence and diffraction specified in advance. In one of these experimental gratings Minkowski finds the light to be so completely concentrated in a single spectrum that the intensity throughout the visual region is a little greater than that in a spectrum of the same mean dispersion produced by two prisms. The deficiency in the grating spectrum is less than the absorption and reflection losses in the prisms, a result offering great encouragement to a further study of the technique of ruling.

The new screw for the second machine has been completed and will be finally tested as soon as the operating nut and a modified driving connection for the plate carriage are ready. The grinding was done with the screw in a vertical position, a procedure which has proved to be a profitable departure from custom.

The elastic deformation of the screw when in the ruling position has been calculated for its own weight alone and for the added weight of the nut and

spacing gear, the latter more or less completely counterweighted. The results show that it will be advantageous to omit the counterweight.

AUDITORIUM AND EXHIBIT HALL

Many thousands of visitors to Mount Wilson during the year have made use of the facilities afforded them by the astronomical exhibit, which is open daily, and the auditorium, in which a popular lecture is given each Friday evening previous to visual observations with the 60-inch telescope. To prevent overcrowding of the lecture room, the system of issuing tickets of admission on application has been retained, but the use of such tickets at the 60-inch telescope has been discontinued. As a result, every Friday-evening visitor to Mount Wilson

has the opportunity of observing with this instrument.

The hours of admission to the 100-inch telescope building, which is open to the public each day, have been somewhat extended, especially on Sundays and holidays. While no record is kept of the number of visitors who see the astronomical exhibit and the demonstrations of the 100-inch telescope, a fair estimate is of the order of 50,000 to 75,000. Actual counts show, however, that about 12,000 have made observations with the 60-inch telescope during the year.

CONSTRUCTION AND MAINTENANCE

ENGINEERING AND DESIGN

The detailed design of the modifications in the 60-foot tower telescope and the reconstruction of the 10-inch photographic telescope to provide for the addition of a photovisual lens and mounting have been the major problems of the engineering department, which, as in past years, has been under the charge of E. C. Nichols, assisted by H. S. Kinney. Other important apparatus for which designs have been completed include a photoelectric spectrophotometer; the 114-inch Schmidt camera of the coudé spectrograph; a small spectrograph for use at the primary focus of the 100-inch telescope; a scanning comparator for examining 5×7-inch plates; apparatus for testing the microphotometer used for direct measurements of line-intensities in the solar spectrum; a Schmidt camera of the block type; a new cell for the Cassegrain mirror of the 60-inch telescope; and a new plateholder designed for photographing the moon.

Drawings for publications and for the annual exhibit in Washington have occupied considerable time in this department.

INSTRUMENT AND OPTICAL SHOPS

The instrument shop has remained throughout the year under the charge of Albert McIntire. More than a third of its time has been given to the construction of equipment for the 60-foot tower telescope. Additional instruments and apparatus have included the 114-inch Schmidt camera and plateholder mounting; the F/0.67 Schmidt camera; the photoelectric spectrophotometer; the prime-focus spectrograph; a lunar plateholder; the solar-spectrum microphotometer; modifications of two of the Cassegrain spectrographs; and a coelostat for the exhibit room on Mount Wilson. Some forty other instruments or pieces of apparatus have been constructed in part or in whole. Repairs of the equipment on Mount Wilson and in Pasadena have

required about 14 per cent of the time of the instrument shop.

The optical shop, in charge of John S. Dalton, assisted by Don O. Hendrix, has constructed the prisms, mirrors, and some of the lenses for the photoelectric spectrophotometer, the focal-plane spectrograph, the solar microphotometer, and a planetary camera. A 22-inch pyrex mirror to replace the elliptical plane mirror of the 60-foot tower telescope has been completed, and the elliptical mirror itself has been tested and slightly refigured for use at the Cassegrain focus of the 60-inch telescope. One of the surfaces of the correcting lens for the 60-inch telescope has been reground and figured to a spherical curve, and work has been commenced upon the components of the 10-inch photovisual lens.

In cooperation with the California Institute of Technology the Observatory has planned to grind and figure the 72-inch concave mirror for the 48-inch Schmidt telescope on Palomar Mountain. This plan will save much time in the completion of the telescope because of the heavy demands upon the Institute's optical shop during the figuring of the 200-inch mirror. The grinding machine has been completed and the disk has already been shaped and partially ground. The 60-inch plane mirror, originally used in testing the 100-inch mirror, will be loaned to the Institute to aid in figuring the 48-inch correcting plate.

A 36-inch pyrex disk, the property of

the Fund for Astrophysical Research, has been figured in the optical shop to a spherical curve with a radius of 19 feet. This mirror has been loaned to the Observatory and is now in use in the coudé spectrograph. The work on the mirror, as well as that on the 72-inch disk, has been carried on by additional opticians under the general supervision of our optical staff.

BUILDINGS AND GROUNDS

The remodeling of the 60-foot tower telescope and the painting of the 150-foot tower telescope have been the chief undertakings on Mount Wilson during the year. Additional portions of the road on the summit of the mountain and some areas near the 100-inch telescope building and the Monastery have been paved in order to reduce difficulties with dust. All this work has been under the charge of A. N. Beebe, Superintendent of Construction. Painting and repairs of buildings on Mount Wilson and in Pasadena have been continued as usual.

After more than 20 years of service the steel cables of the hoist and observing platform in the 100-inch telescope dome have been renewed, the difficult work of replacement being carried out by Sidney Jones, Engineer, and Kenneth de Huff, Assistant Engineer. The construction of new switchboards for the 60-foot tower telescope and the installation of the complicated system of electrical wiring have also been completed by these engineers.

THE LIBRARY

During the past year 289 volumes have been added to the library, 35 by gift, 59 by purchase, and 195 by binding; the total number is now 14,032, with over 10,000 pamphlets. The number of serial publications received regularly in 1939

is 134, of which 42 are gifts and exchanges, as are also the publications, appearing at irregular intervals, of more than 200 observatories and research institutions. The library has also a collection of about 2500 lantern slides.

GEOPHYSICAL LABORATORY¹

L. H. ADAMS, DIRECTOR

The origin and evolution of the Earth have presented a continuing challenge to intelligent man. Throughout succeeding generations, each adding its quota of observations, hypotheses, and speculations, a large body of information bearing on the nature of our Earth and its component materials has accumulated. Especially during the past century, geology, the Earth science, has made rapid strides toward affording a clearer picture of the Earth and of those natural processes that, operating on a very large scale, profoundly modify Earth features and Earth materials. We now know that the framework of the crust of the Earth is composed of granites, basalts, peridotites, and other igneous rocks. All other rocks are derived from these primary materials by subsequent physical or chemical changes. The formation of the igneous rocks and their constituent minerals from molten silicate masses—called magmas—is one of the fundamental problems of Earth history. It is not surprising, then, that upon the establishment of the Geophysical Laboratory the first problem to be attacked involved the melting temperature and chemical composition of some of the important rock-forming minerals, and that similar studies have continued to be one of the major activities of the Laboratory.

Of the ninety-two elements or fundamental substances known to the chemist, ten make up about 99 per cent of the average composition of the igneous rocks. Although we are primarily concerned with the chemistry of these ten chemical substances, our problem is far

from simple. There is a discouragingly large number of combinations of these ten things. For effective progress in this direction the general problem must be divided into smaller units; the relations of the substances to one another are to be discovered only by grouping the variables—"unknowns"—and investigating the groups separately.

The ultimate source of an igneous rock is its parent magma, a molten solution of complex silicates with minor amounts of the rarer chemical elements of the Earth's crust. Rocks are formed from this magma by a crystallization, in whole or in part, of this molten solution, and are produced according to definite physical and chemical laws operating on a large scale in Nature. Geological problems may often be solved most effectively by well-known methods in the fields of physics and chemistry.

Let us consider more specific questions about the origin of these materials. When a magma crystallizes to form an igneous rock or rocks, at what temperature does this crystallization process begin? Does crystallization begin at the same temperature in two magmas of different chemical composition? Do all the minerals separate simultaneously? If not, what is their order of crystallization? Does a magma of a particular chemical composition always yield the same rock or rocks? If not, what chemical and physical processes operate to yield the different rocks?

Questions arise also concerning the individual minerals found in the igneous rocks. Do all minerals always have a constant chemical composition? If not, what factors influence the composition of

¹ Situated in Washington, District of Columbia.

certain minerals? What is the origin of zoned crystals (crystals whose optical properties under the microscope indicate concentric zones of different but related chemical composition)? Why do certain minerals in the igneous rocks appear corroded as though they crystallized and subsequently were partly dissolved? Why do some minerals show reaction rims (mineral grains with a surrounding rim of a different mineral)?

These inquiries are but a few examples of the specific problems that engage our attention in studying the nature and origin of our Earth, and its physical materials. It is important to indicate briefly how these problems have been attacked and to summarize our progress toward a better understanding of the origin of the igneous rocks.

The field geologist, by examining the various igneous rocks in all parts of the world, and their relations to one another and to the surrounding rocks, has accumulated a large body of observations; the petrographer, studying these same rocks in detail by means of thin sections under the microscope, has contributed a large number of facts concerning the more minute relationships of the several minerals to one another; and the analytical chemist in turn has supplied information about the chemical composition of the rocks and their mineral components. It is this combination of observations that has raised the questions concerning the nature of the processes by which igneous rocks have formed and has posed the problem to the physicist and chemist: What laws govern the behavior of a silicate solution of the ten predominant chemical oxides?

Just as the accumulation of the basic information of geology has been brought about through the labors of investigators in many fields, so the elucidation of these facts is being accomplished by the combined efforts of a group of experts. In the experimental study of silicate solu-

tions comparable to the rock magmas at high temperatures and pressures we have a conspicuous example of cooperative enterprise, requiring specialized training in many branches of physical science. High temperatures and pressures must be produced and accurately measured; the chemical composition of the artificial rocks must be accurately controlled; the identification of the synthetic minerals needs to be carried out by special methods applied to the petrographic microscope; the highly developed technique of X-ray analysis must be utilized for the identification of crystalline phases, especially those involving polymorphic forms and solid solutions; and physical methods of the utmost precision are required for measuring thermal effects in order to know the heat changes that occur when one gram or one ton of a mineral melts or crystallizes.

In the Geophysical Laboratory such a group of investigators, composed of geologists, physicists, and chemists, has been collaborating for over thirty years in a unified program, and more than a thousand articles describing the various investigations have appeared in the scientific journals. Proceeding from the simple to the complex and introducing variables one at a time, we have been able to make substantial progress toward the solution of the problem of rock formation. By way of brief review, it may be appropriate to recall that at the outset no suitable basis for temperature measurements was available and that only after the establishment, by means of the gas thermometer, of an absolute scale for high temperatures did it become possible to deal satisfactorily with melting points of the common minerals. The next step in the systematic study of silicate solutions composed of rock-forming oxides was an investigation of the effect of temperature on the behavior of the individual substances. Even for silica, the most abundant of these oxides,

adequate information concerning the melting point, and concerning the conditions under which the several crystalline forms are produced, was not at hand. Furthermore, instead of natural rocks and minerals, artificial ones, prepared from pure chemicals, were used. For these simple synthetic mixtures, a careful control of chemical composition is possible, whereas a natural specimen of even a simple mineral like quartz usually contains small amounts of other minerals as microscopic inclusions which serve only to confuse the investigator.

Upon this foundation we have gradually erected what we believe to be an enduring framework of information concerning mineral fusion. Numerous detailed studies of mixtures containing two components and three components have been carried out and the results summarized in past reports. Although no study of a complete quaternary, or four-component, system has as yet been finished, experiments on three of the most important of these are now in progress. The hopes of the pioneers in this field, that actual rock-forming processes would be amenable to direct study in the laboratory, have been realized, and we now face the future with entire confidence in the success of experiments that involve the more severe conditions of high temperatures combined with high pressures and the presence of volatile components, the most important of which is water.

Most of our early studies on equilibrium in silicate mixtures were confined to dry melts and atmospheric pressure. These results may perhaps be regarded as merely the groundwork for the more complete picture of rock formation. The importance of laboratory experiments on silicate systems containing water and other volatile constituents under pressure may be illustrated by considering the behavior of a large body of molten

magma contained in a subterranean reservoir. Upon cooling, the magma begins to crystallize and a large part of the mass ultimately forms igneous rock. Owing to selective crystallization, those chemical constituents that are present in the largest amount or are most insoluble are removed from the solution as a crystalline aggregate. Gradually there is a concentration in the residual solution of the rarer constituents, including water and various gases. In the late stages of this crystallization the water and other volatile constituents, and also the rare elements, are present in relatively large amounts. Valuable metals may become segregated in this way and deposited along fissures in the already cooled igneous mass or in the surrounding rocks. The reactions of these late hydrothermal solutions and the alteration of the igneous rocks are important chemical processes which require thorough and careful study. Realizing that no experiments on dry melts alone can give us a complete and adequate picture of rock and mineral genesis, we plan to press vigorously the work on aqueo-igneous fusion.

An important measure of scientific progress in any field is the discovery of relationships that have a general bearing on the subject under investigation. Constant attention to general relationships has facilitated our work, which at first glance may appear to be of formidable complexity. But from an unconsolidated array of individual measurements it is often possible to evolve a compact generalization, which at once illuminates the problem in hand and minimizes the number of measurements required for a satisfactory solution.

In the following sections the significant features of current and recently completed investigations at the Geophysical Laboratory are outlined. Most of the work is being carried out as a

part of the continuing program of the Laboratory, with the expectation that the technical results and the relation-

ships derived from them will gradually enable us to know more about the nature and geologic history of the Earth.

ANHYDROUS SILICATE SYSTEMS

Rock-forming pyroxenes. No group of rock-forming minerals has proved of greater interest or complexity than the rock-forming pyroxenes. The metasilicate molecules CaSiO_3 , MgSiO_3 , FeSiO_3 , MnSiO_3 , and unknown molecules containing Al_2O_3 , Fe_2O_3 , and TiO_2 , enter into the chemical composition of this mineral group. Several of these compounds occur in two distinct crystalline forms, each of which is capable of entering into solid solution with the other molecules in quite different amounts. These changes from one crystal form to another, with consequent changes in chemical composition, play an important part in the cooling history and the progress of crystallization of a rock magma.

The system CaSiO_3 (wollastonite, pseudowollastonite)— $\text{CaMg}(\text{SiO}_3)_2$ (diopside), recently completed and now in manuscript [Schaerer, Bowen] shows that up to 22 per cent of diopside enters into the low-temperature form of CaSiO_3 (wollastonite), while none or almost none enters in solid solution into the high-temperature form (pseudowollastonite). Because of these relations the inversion temperature of wollastonite to pseudowollastonite is raised over 200°C and wollastonite solid solutions actually appear on a small portion of the liquidus surface. No appreciable amount of CaSiO_3 enters diopside in solid solution.

Satisfactory progress has been made in our studies of the nature and relations of the molecules of the aluminous pyroxenes. The fundamental system $\text{FeO—Al}_2\text{O}_3\text{—SiO}_2$ is almost completed, and portions of two planes through the quaternary system $\text{CaO—FeO—Al}_2\text{O}_3\text{—SiO}_2$ have been studied [Schaerer].

These quaternary data, which will take several years for completion, are essential for an understanding of the rôle of Al_2O_3 in the augites, one of the commonest rock-forming pyroxenes.

Leucite—anorthite—silica. In order to ascertain the chemical nature of the residual liquids from fractional crystallization in systems which involve both early- and late-crystallizing minerals, we have been studying a series of such systems. Measurements are nearly complete for the system leucite—*anorthite*—silica, which combines *anorthite*, one end-member of the plagioclase feldspars, with the alkali-alumina-silicates leucite and potash feldspar [Schaerer, Bowen]. The field of *anorthite* occupies a large part of the ternary phase diagram, and fractional crystallization would yield residual liquids very rich in potash feldspar and silica.

Nepheline—anorthite—silica. Quenching experiments are in progress on the portion albite—*anorthite*—silica in order to trace the composition of the solid phases during crystallization of mixtures of plagioclase feldspar and silica [Schaerer]. The surprising ease of crystallization and the rapid rate of attainment of equilibrium between crystals and liquid in these siliceous compositions have been very fortunate. Only in compositions very close to the albite-silica side line, in the ternary plot of *anorthite*—albite—silica, has crystallization been difficult and has the attainment of equilibrium between crystals and liquid been slow. The presence of *anorthite* lowers viscosity of the melts very rapidly and accelerates the rate of attainment of equilibrium.

Alkali silicates. Although the simple

silicates of the alkalis do not occur as rock-forming minerals, investigations of the equilibrium relations in systems of the alkalis with silica are of significance in geochemistry because of the relation to more complex systems containing alumina, as well as alkalis, the study of which is necessary for the interpretation of pegmatite formation. Systems containing lithia have a bearing on the formation of, and replacement in, the lithium pegmatites. The system $\text{Na}_2\text{SiO}_3\text{—Li}_2\text{SiO}_3$ has now been completed [Kracek]. There is an intermediate compound, NaLiSiO_3 , which melts incongruently at 847°C , and between this compound and Na_2SiO_3 there is a complete series of solid solutions with a minimum at 845°C at the composition 38.5 per cent Li_2SiO_3 . The compound NaLiSiO_3 forms a partial series of solid solutions with Li_2SiO_3 with a composition ranging from 83 to 100 per cent Li_2SiO_3 .

The binary system $\text{Na}_2\text{SiO}_3\text{—Li}_2\text{SiO}_3$ is a binary join in the more comprehensive system $\text{Na}_2\text{O—Li}_2\text{O—SiO}_2$, which is now under investigation at the Laboratory. The measurements are nearly complete, and a manuscript is in preparation on the system $\text{Na}_2\text{SiO}_3\text{—Li}_2\text{SiO}_3\text{—SiO}_2$, which forms another portion of the larger ternary system.

The quaternary system lime—magnesia—alumina—silica. This system determines the mutual melting relations of several important rock-forming minerals, for example, the pyroxenes CaSiO_3 (wollastonite, pseudowollastonite), $\text{CaMg}(\text{SiO}_3)_2$ (diopside), and MgSiO_3 (enstatite, clinoenstatite), the olivines Mg_2SiO_4

(forsterite), CaMgSiO_4 (monticellite), Ca_2SiO_4 (larnite), and $\text{Ca}_3\text{Mg}(\text{SiO}_4)_2$ (merwinite), the melilites $\text{Ca}_2\text{MgSi}_2\text{O}_7$ (akermanite) and $\text{Ca}_2\text{Al}_2\text{SiO}_7$ (gehlenite), and also cordierite, corundum, spinel, mullite, and tridymite. Some years ago, in a paper from this Laboratory, Andersen published results for the system forsterite—anorthite—silica, which is within this quaternary system. A large number of measurements have been made on the system anorthite—diopside—silica [Greig], and this work is being continued.

During the past year other experiments of an exploratory nature on portions of this quaternary system have been initiated [Schairer, Osborn]. Measurements are nearly complete for the ternary system gehlenite—akermanite— CaSiO_3 (wollastonite, pseudowollastonite). Complete data for the liquidus have been obtained, and most of the three-phase boundaries have been determined. Because of the relations presented by these components, the ternary system is of particular interest. Although there is no ternary eutectic, there is a minimum with *two* solid phases, one a melilite (gehlenite-akermanite solid solution) and the other a pyroxene, CaSiO_3 . The results in this ternary system show us the mutual melting relations between a simple melilite and a simple pyroxene, two of the rock-forming minerals. Preliminary studies in other ranges of composition indicate that there are but few binary or ternary systems within the quaternary system—which complicates the problem and makes progress slower.

SYSTEMS CONTAINING WATER AND OTHER VOLATILE COMPONENTS

Calcium sulfate deposition from sea waters. Many deposits of calcium sulfate of sedimentary origin are found in Nature in the form either of gypsum or of anhydrite. Aside from the economic

value of these deposits, the conditions under which each mineral may have been deposited are of considerable geological interest. In the investigation of the system calcium sulfate—water, re-

ported last year, it was shown that the relative stabilities of gypsum and anhydrite were determined solely by their solubilities. Since many deposits of gypsum and anhydrite are recognized to be of marine origin, it is obvious that the determination of their solubilities in various concentrations of sea salt would furnish an improved basis for their geological interpretation.

During the past year determinations of such solubilities were made at 30°. These showed that the solubility of gypsum as well as that of anhydrite first increases rapidly in the presence of increasing amounts of sea salts, goes through a maximum at about twice normal salinity, and then gradually decreases, the intersection of the two curves taking place at 4.6 times normal salinity. The composition of normal sea water is unsaturated with respect to calcium sulfate, and with the existing proportion of salts in sea water the saturation point is attained only when the total salt concentration is 3.5 times that of the normal salinity, at which point the solubility curve of gypsum is reached. This brine must be concentrated to 4.6 times normal salinity before the point is reached where the solubility curves of gypsum and anhydrite intersect, and above which the latter becomes the stable phase. Thus, when evaporation of a marine basin takes place at 30° (and in all probability also at the somewhat lower temperatures that might be expected), a large portion of its calcium sulfate content will always be deposited as gypsum. The sedimentary deposits of pure anhydrite found in many places may have been derived (at least in part) from originally deposited gypsum, or they may have been formed at or above 42°, the transition point of the two minerals.

Quenching experiments in high-pressure steam. Since the completion of experiments on the binary system water—

sodium disilicate [Morey, Ingerson], measurements have been made on mixtures in the ternary system H_2O — Na_2O — SiO_2 , intermediate between the metasilicate and disilicate, at pressures up to 2000 pounds of steam. These measurements were temporarily interrupted on account of the redesigning and rebuilding of the apparatus in order to attain higher pressures. The new apparatus is performing satisfactorily and the measurements are now going forward.

Solubilities of alkali hydroxides and carbonates. For an understanding of pegmatite formation and hydrothermal alteration of minerals it is necessary to investigate the stability (in the physicochemical sense) of mixtures of water and various silicates. More specifically, we need quantitative information on the very complex system Na_2O — K_2O — Al_2O_3 — SiO_2 — H_2O at temperatures below about 600° C. Such information may only be obtained by a systematic attack on this five-component system, beginning with the simple binary systems and including also aqueous solutions of alkali hydroxides and carbonates.

Last year measurements with the new filter autoclave were reported and data were presented for the system H_2O — NaOH — Na_2CO_3 , in the temperature range from 60° to 70° C [Morey, Burlew]. In extending these measurements to higher temperatures we considered it advisable, because of the difficulty in completely excluding CO_2 , to determine the curve of simultaneous saturation for NaOH and Na_2CO_3 over the entire range, that is, along the boundary curve between the fields of NaOH and Na_2CO_3 in the ternary system H_2O — CO_2 — Na_2O . Since the boundary curve, over most of its course, is near the side H_2O — NaOH of the component triangle, it is possible by experiments at comparatively few temperatures to calculate the solubility in the binary system itself.

This boundary curve of simultaneous

saturation has now been carried up to 280° C. Some experiments have been completed at 300°, in solutions saturated only with NaOH. The isotherm for 270° is almost complete and represents the solubility of NaOH in solutions containing progressively less CO₂. At lower temperatures the proportion of CO₂ present in the solution is so small that the solubility relations can be determined with less certainty. Since at 270° the CO₂ content at double saturation is much greater (3.2 times as large as at 180°), the course of this isotherm can be determined with greater precision.

Solubility of water in alkali feldspar compositions. Studies of the systems NaAlSi₃O₈ (albite)—water and KAlSi₃O₈ (orthoclase)—water at high temperatures and pressures have been extended during the past year to include intermediate alkali feldspar compositions [Goranson]. An investigation of the behavior of a mixture containing 70 per cent albite and 30 per cent orthoclase has now been completed, and its melting curve is found to be approximately parallel to that for pure albite but displaced downward on the temperature axis by about 60°.

Previous experiments indicated that a minimum might possibly exist at some pressure exceeding 5000 bars. In order to investigate the properties of these hydrous silicate mixtures at much higher

pressures, new apparatus is being constructed with which we hope to triple the present pressure range while still maintaining the high temperatures.

The system water—arsenous oxide. In this system mixtures containing only small amounts of water are exceedingly viscous and long periods of time—several weeks in many cases—are required for crystallization. At the higher temperatures arsenolite is the primary phase, while at lower temperatures claudetite separates. Some points have been determined on the high-temperature end of the solubility curve. The experiments are proceeding slowly but quite satisfactorily [Morey].

The system Na₂O—B₂O₃—SiO₂. About three years ago experiments were started on this ternary system. Initial difficulties in obtaining crystalline preparations over considerable parts of this system have been overcome by more precise control of temperatures during the crystallization process. Some very puzzling observations were explained when it was found that the field of the compound Na₂O·B₂O₃ spreads over the join between the disilicate and diborate. Evidence already obtained indicates that at the lowest ternary eutectics metaborate coexists with a higher borate and a silicate. By more careful control of temperature conditions, the low-temperature region is proving amenable to satisfactory measurement [Morey].

EFFECT OF PRESSURE AND TEMPERATURE ON SIGNIFICANT PROPERTIES OF SOLUTIONS

In any study of processes involved in the formation of the Earth's crust we must recognize pressure as well as temperature as a potent factor. Our work with solutions at moderate pressures during the past year has been a continuation of the study of the effect of pressure on heterogeneous equilibria through an investigation on significant properties of solutions throughout a

range of temperatures and pressures [Gibson, Loeffler]. This year special attention has been given to the correlation of our observations on the behavior of liquids and liquid solutions under pressure, to their interpretation in the light of the rapidly expanding theories of the liquid state, and to the extension of these ideas to solutions.

The results of this work support two

conclusions of immediate geophysical interest: (a) It seems certain that at high pressures the internal energy of liquids due to the repulsive forces between the molecules is so large that the temperature of the liquids will rise when they begin to expand. (b) Recent theoretical investigations of Lennard-Jones and Devonshire reopen the question of a critical point on the melting curves of solids. Weighty evidence is now forthcoming which suggests that there may exist temperatures above which no pressure will prevent a solid from melting.

Aqueous solutions. Continuing the studies on aqueous solutions reported last year, we have obtained P — V — T data for ten solutions of lithium bromide in water covering the whole range of concentration and extending over the pressure range 1 to 1000 bars and the temperature range 25 to 95° C. These results will be analyzed shortly by methods suggested in the following paragraphs.

Pure liquids. In order to supply a much-needed empirical background of information, we measured the specific volumes, thermal expansions, and compressions of a number of common liquids of well-known chemical character and some mixtures of pairs of these liquids. We developed suitable equations whereby the specific volumes, expansion coefficients, and compressibilities of these liquids could be precisely computed at any point in the temperature—pressure field from 1 to 1000 bars and 25 to 95° C. From these results the important thermodynamic quantities $(\partial P/\partial T)_V$, $(\partial E/\partial V)_T$, $C_P - C_V$, $(\partial C_P/\partial P)_T$ were obtained at the desired pressures and temperatures. Proceeding in this way we were able to employ a useful technique for interpreting such results, viz., an examination of the variation with temperature of a given property when the volume of the liquid is kept constant and when, presumably, therefore the mean distance between the molecules is un-

altered. Noteworthy results are that the expansion coefficients, the compressibilities, and the coefficients $(\partial P/\partial T)_V$ and $(\partial E/\partial V)_T$ all decrease as the temperature is raised at constant volume. We believe that the decrease in $(\partial E/\partial V)_T$ with temperature at constant volume is of great significance and arises from the increase in the repulsive internal pressure of the liquid due to the increase in the randomness of the distribution of the molecules produced by rise of temperature. (The quantity $(\partial E/\partial V)_T$ is taken as a measure of the difference between the attractive and repulsive internal pressures in the liquid.)

In this work we have extended the use of the Tait equation $\left(k = C \log \frac{(B+P)}{B}\right)$ by showing that it reproduces the observed compressions in all cases, that the constant C is the same for all the benzene derivatives, and that, if it be assumed that $(B+P)$ represents the repulsive internal pressure of the liquid, the quantity $\left((\partial E/\partial V)_T + (B+P)\right)$ being the attractive internal pressure P_A , then P_A is independent of temperature at constant volume.

By this analysis we are able to split up the internal pressure, $(\partial E/\partial V)_T$, into its components, the attractive pressure P_A (3 to 8 kilobars), which depends chiefly on the average distance between the molecules and hence on V only, and the repulsive pressure $(B+P)$ (0.5 to 2 kilobars), which varies so rapidly with the distance between the molecules that it depends on their distribution as well as on their average distance apart.

Liquid mixtures. The same type of analysis has been applied with similar results to pressure—volume—temperature data for mixtures of liquids. In addition, a formula has been developed for computing the attractive pressure of the liquid mixture in terms of constants

for the pure components and the composition of the mixture expressed in terms of "general volume fractions."

Effect of pressure on optical absorption. Although aniline is colorless and nitrobenzene is faintly yellow, mixtures of these liquids are of a deep orange color, and in general it is known that any aromatic amine dissolved in a nitro compound gives a highly colored solution. We have found that the absorption of light by these solutions is strongly affected by changes in hydrostatic pressure, the absorption of light being pushed toward longer wave lengths as the pressure is raised. In view of the novelty of this effect, we investigated it in detail, studying solutions of aniline, dimethyl aniline, diphenylamine, triphenylamine, nitrophenol, and paranitroacetanilide in aniline, the nitroanilines and some dyes in neutral solvents, nitrosobenzene in benzene and in aniline.

We found that (a) in all cases where a color change on mixing occurred, the absorption of light was pushed to longer wave lengths by rise of pressure; (b) except in the case of nitrophenol in ani-

line, large changes of temperature did not affect the absorption of light by the solutions; (c) in solutions of aniline in nitrobenzene the absorption coefficient of the solutions could be simply expressed in terms of the concentration. An analysis of the results in the light of physical theories of organic compounds led to the conclusion that the color was due to intermolecular action but that no compound in the usual sense was formed in the solutions. The molecules interact on collision, producing a temporary electronic rearrangement which affects the absorption of light but does not give a thermodynamically stable compound.

Our results show that studies of the combined effects of pressure and temperature on solutions shed light on two problems: (a) the absorption of light or color of organic compounds, (b) the significance of certain criteria, such as color, in studies of the possibility of compound formation in solutions. It is concluded that ordinarily no sharp distinction between compound formation and other forms of intermolecular action may be made.

PROPERTIES OF GEOLOGICAL MATERIALS

X-ray methods. In the process of analyzing the crystal structure of the gold and silver telluride minerals constituting the sylvanite group, it has been found desirable to use the equi-inclination layer-line photographs obtained with the Weissenberg X-ray goniometer, as well as equator photographs [Tunell]. The rotation factor entering into the intensities of the diffraction spots on equi-inclination layer-line films had not previously been worked out, and was determined in order to render possible the use of such films in structural work. A chart, computed and plotted for the rapid determination of the rotation factor appropriate to each diffraction spot, has proved very useful.

A set of stencils and numbered strips and a "sorting board" for use in calculation of double Fourier series has been constructed. This device and the chart mentioned above have been used in independent determinations of the parameters in the structures of minerals of the sylvanite group by Fourier-Patterson methods, supplementing previous determinations.

Occurrence of diamonds in meteorites. Small black grains, embedded in a graphitic mass in a cavity in a specimen of the Canyon Diablo iron meteorite, have been identified by means of their X-ray powder spectrum as diamonds [Ksanda]. In collaboration with E. P. Henderson, of the U. S. National Museum, small indi-

viduals from 0.1 to 0.6 mm in size were removed from the middle area of the cavity by etching with nitric acid. Very small fragments are transparent and their optical properties agree with those of diamond. Under the microscope the grains are of uniform, dull rich black color, and consist of very fine-grained, porous clusters of minute individuals. The distribution of diamond through the Canyon Diablo meteorite is not uniform and it occurs only in the nodules and cavities.

Raman spectra. The Raman effect is related to the constitution of individual molecules. There are four principal physical methods for obtaining information concerning the structure and nature of molecules. These methods, which are electron diffraction, X-ray spectra, absorption and emission spectra, and Raman spectra, pertain to different effects of molecular constitution.

Electron diffraction enables one to estimate the distances between atoms in a molecule, but its application is limited to gaseous molecules or to thin layers of solids. X-ray spectra give the same information, but this method is convenient only when the atoms have a reasonable mass. The only direct evidence obtainable by these two methods is in connection with the interatomic distances. Emission spectra, similarly, give information concerning interatomic distances in molecules and the energies of the atoms within the molecule. This method must be confined to relatively simple molecules, and is applicable only to the gaseous state. Absorption spectra, particularly in the ultraviolet and infrared regions of the spectrum, provide information concerning molecular structure and also interatomic forces. In general, the same may be said of Raman spectra, the difference lying in the amount of information obtainable, the ease with which it may be procured, and the simplicity of interpretation of the observed results. The infra-

red effects are usually dependent on the vibrations of one or more of the light atoms, such as hydrogen, in relation to one or more of the heavier atoms. For Raman spectra less elaborate equipment is required, and the spectra obtained are simpler and easier to interpret, because the vibrations which indirectly give rise to the Raman effect are usually the fundamental vibrations of the atoms in the molecule. The antisymmetrical vibrations which appear strongly in infrared absorption frequently appear weakly in the Raman effect, although the converse is rarely true. The Raman effect has the great advantage of being applicable to almost all transparent substances and of being independent of the state of aggregation. It may be employed in the investigation of solvents, solutes, gases, crystals, amorphous compounds, and liquids irrespective of whether the material is of organic or inorganic origin.

In general, the information directly obtainable from Raman spectra consists of the composition of the molecule, the forces between the atoms in the molecule, the arrangement, in many cases, of the atoms in space, the type of chemical linkage, and, on occasion, the interatomic distances—in short, the composition, structure, and nature of the molecules in the state in which they are usually encountered. The geochemist is interested in the Raman effect because of the information that it affords on the constitution of liquids and crystalline solids. The physicist finds a further use for the Raman effect as a means of investigating interatomic forces and energy levels within the molecule.

During the past year a comprehensive monograph has been prepared and published [Hibben] on the Raman effect and its chemical applications, together with a complete collection of all data that have been obtained in this field.

Optical methods. The textures seen

by the observation of polished surfaces of opaque ores in plane and polarized light with the reflecting microscope give information concerning the genesis of the opaque ore minerals. Textures which are produced under controlled conditions in the laboratory assist in such interpretations of the relations of these minerals [Merwin, Greig]. The published work from this Laboratory on the copper-iron sulfide minerals [Merwin, Lombard (1937)] provided the basis for preparing suitable samples for further studies. Various copper-iron sulfide minerals, because of their differences in color, are easily distinguished in polished sections. We plan to prepare photographs in color of the important ore textures.

Before 1917 almost no observations of the refractive indices of the finer-grained pigments had been made, but at that time results on some of these materials, many of which are naturally occurring mineral substances, were presented in a publication from this Laboratory. During the intervening period many new pigments have come into use. At Harvard University the Fogg Museum has spent several years making a collection of artists' colors and other pigments. The difficult microscopical examination of these materials has been completed [Merwin] and the results will be published soon by the Fogg Museum.

Thermal properties of rock-forming minerals. There is increasing evidence from field studies of igneous rocks that some molten magmas have dissolved, or assimilated, a portion of the rock mass into which they have been intruded. Objection has been raised that insufficient heat was available to accomplish this assimilation. Before we may apply the laws of physics and chemistry to this geological process, it is necessary to have quantitative information concerning not only the mutual melting relations of all the minerals of the rocks involved in such

processes, but also the latent heats of melting of these rock-forming minerals. As reported last year, a new apparatus was designed for the purpose of making the necessary measurements of heat quantities at elevated temperatures [Roberts]. Although the preliminary results obtained with this apparatus have been highly gratifying, it was necessary to reinvestigate some aspects of the melting and freezing process before a precise determination of the latent heats of melting of rock-forming minerals was practicable.

Once a silicate is melted, it is often difficult to recrystallize it *completely*. A mixture of liquid and crystals, unless the proportions of both are known very accurately, is worthless for the purpose of a latent heat determination. For the two silicates already investigated, Na_2SiO_3 and $\text{Na}_2\text{Si}_2\text{O}_5$, it is sufficient to remelt and recrystallize the sample once or twice without raising the temperature more than a few degrees above the melting point. These two silicates are easy to prepare free from impurity and they melt at moderate temperatures. Although they crystallize readily, the melts may be undercooled and the behavior of the liquid compared directly with that of the solid.

Polymorphism may introduce another complication. The stable form of sodium disilicate, $\text{Na}_2\text{Si}_2\text{O}_5$, has a reversible inversion at 678°C and another at 706° . When crystallized from a temperature above 706° it usually appears as a metastable form, which exhibits neither of these inversions. The metastable modification melts several degrees lower than the stable form and its heat of melting is about 6 per cent greater. When partly melted it inverts to the stable form. Since the stable form has the higher melting point, the inversion results in solidification of the portion previously melted—a sort of “second freezing point” similar to the “second boiling point” ob-

served in melts with a volatile component. Below 678°, the stable form is obtained at once.

Electrically charged multilayers. The methods, previously reported, for studying the electrical properties of multilayers built up from monomolecular films of long chain polar molecules have been applied to the investigation of the cause of the electrical effects [Goranson, Zisman]. When stearic acid is spread as a monomolecular film on the surface of an alkaline aqueous solution of a calcium salt, the polar groups of the acid react with adsorbed calcium ions producing neutral calcium stearate. This in turn binds more adsorbed calcium ions by the ion-dipole forces. Multilayers plated from such a film will have a volume distribution of charge as a result of the occluded calcium ions. If the multilayer be plated on a metal base, the resultant electrical effect is similar to that of a volume-polarized medium, because equal and opposite charges are induced in the metal support.

The same methods are also well adapted for study of an aspect of the adsorptive process which has as yet not received much attention, but which may be important for biophysics. Data already obtained indicate that the field intensity surrounding the adsorbed ion is a significant factor and that small or high-valency ions yield uncharged multilayers because their high electrical field intensities are able to hold the neighboring water layer with its cloud of negative ions.

The fabric of rocks. Motion involved in the formation or deformation of rocks produces a preferred orientation of the constituent mineral grains. The symmetry of the orientation pattern reflects the symmetry of the motion. These tenets are the basis of modern structural petrology and were developed by the Austrian geologists Sander and Schmidt between 1911 and 1925. Studies of these

rock fabrics are called "petrofabrics," where "fabric" denotes all the spatial relations of a rock from the lattice of the mineral grains to the largest mountain structures.

Much of the work that has been done in petrofabrics is purely descriptive in character, and in many studies must remain so until specific data are available on the deformation and orientation of the important rock-forming minerals under known conditions of stress and motion. The attack on the problems should be twofold: a quantitative laboratory study of mineral and rock deformation under known conditions, and an application of this information to rocks deformed under specified types of stresses.

The methods of petrofabrics have been applied chiefly to studies of metamorphic rocks, particularly to those that have been subjected to several periods of metamorphism, and structural elements have been determined that are not readily apparent by any other means. We have been able to apply these methods to some problems of igneous and sedimentary rocks [Ingerson]. Our work has not been merely descriptive; the problems were chosen for the purpose of adding to our knowledge of the geologic history of certain areas. It has been possible to stay away from controversial questions of the mechanics of mineral deformation that await laboratory experiments under controlled conditions. This has been accomplished by making use of various types of orientation, such as girdles about fold axes—established empirically and having a significance independent of the way in which the individual mineral grains behave during deformation—and also by comparing fabrics of specimens of known and unknown origin without regard to the origin of the fabrics.

Studies already completed on two intrusives that contain many inclusions

of other rocks have yielded criteria for determining the origin of inclusions and for telling whether such an intrusion has undergone regional metamorphism. Studies of ripple marks and pseudo-ripple marks in sedimentary rocks have afforded criteria for distinguishing between these two structures and telling something about the origins of different kinds of pseudo-ripple marks. Work is in progress on the differential abrasion of quartz in different crystallographic directions and on the preferred orientation of quartz in sandstones.

Densities of materials. In the determination of density of small volumes of either liquids or very dense solids, the chief difficulty has been to fill a pycnometer in an exactly reproducible way. Accurate densities of a large number of geological materials are required in many of our investigations. In a capillary pycnometer, or micropycnometer, which has recently been devised [Ksanda, Merwin], the filling to a reproducible height is determined by examining the meniscus of the liquid. A narrow horizontal beam

of light reflected from the meniscus furnishes a sensitive criterion for determining the height of the meniscus; the new technique enables us to obtain very accurate density measurements on small samples.

Radium in rocks. During the past year active work on the determination of the small quantities of radium present in rocks and other geological materials has been resumed [Piggot, Urry]. The most sensitive and accurate method of determining radium in small amounts is to measure the ionization current sustained by the disintegration of radon and its products. With suitable precautions it is possible to insure the collection of all the radon in equilibrium with its parent, radium, and there exists no ambiguity in expressing the results in terms of radium even though the measurement is made on the daughter element, radon.

A new and very convenient experimental set-up has been completed and is being used for the measurement of the radium content of cores from the ocean bottom.

FIELD STUDIES

Ocean bottom sampling equipment. Although plans had been made for our participation in the Expedition to the South Seas under the auspices of the National Geographic Society and the University of Virginia, starting in September of this year, and although it had been expected that many cores from the bottom of the Pacific Ocean would be obtained with our portable equipment, the Expedition unfortunately has been indefinitely postponed.

Determination of gravity in the field. The gravity torsion meter has been developed still further and is now in use in the field, where it is passing through the stage of detailed test, especially that of temperature regulation by electrical means [Wright, England]. The gravity-

measuring apparatus is carried inside a stainless steel housing of three concentric cylinders. The tungsten torsion spring, optical system, graduated circle, and other essential parts are mounted inside a cylindrical casting of special aluminum alloy with walls thick enough to maintain a vacuum of 1 mm of mercury. This apparatus fits snugly into the inner cylinder of stainless steel, on the outside of which heating wires of insulated copper (28 gauge) are wound in equally spaced spirals. There are ten heating wires; eight of these are connected in parallel and two in series. Current is drawn from a 6-volt storage battery. A compensating resistance is mounted near the bimetal thermostat regulator to insure sensitive operation. The inner stainless

steel cylinder is separated by a 2-inch air space from the the second cylinder, which, in turn, is separated from the outside cylinder by an insulating layer of balsa wood, 2.5 inches thick. The rear end is closed and is similarly heated and insulated; the front end, likewise insulated, is heated by separate leads and is thermostatically controlled.

To maintain the temperature inside the apparatus constant to 0.01°C is difficult and requires a long period of test to ascertain the exact conditions necessary to accomplish this in the face of wide fluctuations in outside temperatures. These difficulties are gradually being surmounted. The apparatus is being used on a field observing program that is to include a series of gravity measurements across the coastal plain in Maryland and Virginia, where the thickness of the light sedimentary strata varies greatly and affects appreciably the gravity anomaly

values. From these variations it is possible to draw conclusions regarding buried geological structures and the depth to the crystalline rocks.

Petrologic field studies. On several occasions during past years an opportunity has been found for several members of our staff to spend a limited period during the summer months visiting important petrologic regions and familiarizing themselves, on the ground, with the problems of the field geologist. The localities chosen have been those which have received intensive previous study, sometimes by several different geologists, and which are known to present problems directly related to the program of the Laboratory.

Volcanoes in Guatemala. The results of further studies of volcanic activity in this region are reported under the heading "Cooperative Studies."

COOPERATIVE STUDIES

Study of the moon's surface. For several years past the Geophysical Laboratory has cooperated with Mount Wilson Observatory in study of the surface features of the moon. Although the moon's surface has been observed telescopically for more than three centuries, little is known as to the nature of its surface materials or the origin of its strange surface formations; a good photographic map of the moon, free from the defects of maps drawn by observers inadequately trained in the methods of topographic expression, has not yet been produced, and detailed physiographic study of the various lunar land forms is still lacking. It is realized that ordinary processes of erosion, such as exist on the Earth, are absent on the moon, because of its lack of an atmosphere and of surface waters. Sedimentation and sedimentary rocks of terrestrial types can hardly be expected to

occur; more primitive types and structures are observed, and seem to be sufficiently related to terrestrial types so that their detailed physiographic study and classification may aid in the interpretation of certain terrestrial features and thus contribute to the history of the moon and to a better understanding of the history of our planetary system.

In this investigation the Geophysical Laboratory has contributed effectively to the development of methods suitable for the attack on the problem. The nature of the substances exposed on the moon's surface can be ascertained only by detailed study of the effects that these materials produce on sun's rays on reflection; moonlight is reflected sunlight, modified through impact with lunar surface materials. The changes thus produced are of two kinds: (1) a certain amount of plane polarized light is introduced in the visible and ultraviolet and

infrared parts of the spectrum; (2) the relative intensities of different parts of the spectrum are shifted somewhat in moonlight as compared with sunlight. For many years the Geophysical Laboratory has studied and developed methods for the study and analysis of polarized light and has undertaken this part of the observing program with the aid of facilities at Mount Wilson Observatory. For the preparation of a photographic map of the moon the Geophysical Laboratory has also been responsible. The actual production of this series of lunar photographic maps is being accomplished at Mount Wilson Observatory, where the necessary photographs of the moon at different phases are being taken at the Newtonian focus of the 100-inch telescope, and where a special building for the transformation of these photographs has been erected.

The results secured through this inter-departmental cooperation are important; they have been obtained advantageously because the facilities within the Carnegie Institution have been available to the members of the committee charged with this task. The present membership of the Committee on Study of the Surface Features of the Moon, under the chairmanship of F. E. Wright, includes another member of the Geophysical Laboratory, two members of Mount Wilson Observatory, and three Research Associates of the Carnegie Institution of Washington.

Studies of volcanic activity. It is quite natural that the outward manifestations of volcanism should receive serious attention, for they permit us to obtain direct information concerning the interior of the Earth. Since an eruption is only one stage in the complete cycle of activity, a combined field and laboratory study of the events leading up to and following an eruption is essential before we can begin to make generalizations as to the underlying causes. The successful

use of modern physical methods in locating subsurface discontinuities encouraged us to believe that it would be profitable to apply similar methods to the study of discontinuities beneath the surface of an active volcano. We shall have taken a definite step forward in determining the causes of volcanic activity if we can locate the buried and potentially active material and follow it on its way to the surface. It seems quite probable that seismic, magnetic, potential, and sonic studies of an area in which there is continuing activity will eventually afford an explanation of volcanism.

The volcano of Santa María in Guatemala is favorably situated for investigating the dominant type of volcanic activity of our Earth, namely, the explosive type characteristic of volcanoes from which the more siliceous rocks, such as the andesites and rhyolites, are extruded. The year 1902 is of especial interest to the volcanologist on account of the eruptions of almost equal intensity that occurred within six months of each other, first at Mont Pelée on the Island of Martinique, and next at the supposedly extinct volcano of Santa María in Guatemala. A crater was developed on the flank of the ancient cone of Santa María at the 2000-meter level. No further unusual activity was exhibited until 1923, when observers reported that fresh lava was being extruded from the southern portion of the crater. This activity is still continuing, and is evidence of the potentialities existing below the surface. This new edifice, called Santiaguito, has now, seventeen years after its first appearance, an altitude of about 300 meters above the crater floor, and a diameter of roughly 700 meters. The bulk of this structure has been slowly but steadily increasing by virtue of the extrusion of a hot (about 800° C at point of emergence), viscous, porous, and mostly crystalline igneous material. Up to the present time (1939) there has not been

any well-defined flow of lava, but, instead, the freezing of the viscous rock-forming material has permitted the extrusion of ridges, spines, and hot fragmental material. The ridges and spines are often broken down by the pressure exerted against them from below, and as a result the outer surface of Santiaguito consists largely of loosely piled-up rocks, which are often at their angle of repose (about 32°). Intensive fumarole activity exists in various parts of the dome-like structure.

The activity at Santiaguito was studied in 1932 and 1935 by members of the staff of the Geophysical Laboratory. In 1939 the Geophysical Laboratory and the Department of Terrestrial Magnetism cooperated in an investigation of the electrical, magnetic, and other properties [Zies, Gish, McNish] in a portion of the area that immediately adjoins the new volcanic structure. Measurements of electrical ground potential had the desirable feature of permitting continuous records over a period of eight weeks. Similar measurements but of shorter duration were made at our headquarters at El Faro, which is approximately 1200 meters below the dome, and, for purposes of comparison, also on the plain of Quezaltenango, which is about 40 kilometers from the dome and at about the same elevation.

In addition to potential measurements, measurements were also made of the magnetic intensities (especially the vertical intensity) of the region that immediately adjoins the dome of Santiaguito. Several hundred stations were occupied; these varied in elevation from sea level to approximately 2500 meters. The work at Santiaguito calls for considerable expenditure of physical effort on the part of the investigator, but the rapid development of reasonably good roads during the past five years has been a valuable aid. The use of the automobile lent by the Division of Historical

Research was largely responsible for the establishment of so many magnetic stations.

Final conclusion should await the complete analysis of all the data, but it is evident that results of much value have been obtained. It appears that the determination of the relatively large difference known to exist between the magnetic properties of hot lava (800 to 900°C) and cold lava of similar composition will enable us to outline and fix the depth below the surface of the bulk of the hot and potentially active material. It is too much to expect that such a method will fix the dimensions of the much smaller volume represented by the column of lava that issues from the parent mass; nevertheless, it is hoped to find other methods for accomplishing this.

A portable radioactivity meter was used to find out whether the radioactivity of the atmosphere increased as one approached the active dome of Santiaguito. The results indicate that either there is no increase over the usual background count for the elevation at which we worked, or our instrument is not adapted to the determination of small differences. It will be desirable to make another attempt with an instrument that is shielded in such a manner that the bulk of the extraneous radioactivity can be excluded. Temperature measurements of the steam issuing from the fumaroles located on the east flank of Santiaguito were made, and it was found that the temperatures were almost identical with those observed in 1932 and 1935. The temperatures range from 92° to 450° . Preliminary analysis of the incrustations formed by the acid gases escaping with the steam shows that sulfur dioxide, hydrochloric acid, and hydrofluoric acid are the prevailing acid constituents just as they were in 1932 and 1935. Sulfur is forming only at fumaroles the temperatures of which are 100° or less. The

loosely coherent character of the extruded rock permits oxygen from the air to be drawn into the volcanic edifice by the aspirating action of the escaping gases, and free sulfur can be expected only at vents where the temperature is low. Many samples of rock altered by the gases were collected and will be subjected to mineralogical and chemical analysis. In many vents the steam is escaping at temperatures above the critical point and the usual hydrolytic action is therefore held in abeyance. It is now well established that the extrusion does not persist in any one portion of the dome for more than a year or so. The activity in 1939 has shifted its position about 15° to the west from that which it occupied in 1935.

The persistent, intermittent extrusion of masses of hot rock in this region is of interest, and should be studied in greater detail in the future. It is quite possible that the temperature and pressure gradients existing in the lava column permit chilling and solidification of the upper portion and thus allow the pressure developed by the release of gases in the hotter portion below to accumulate to such an extent that the upper mass is literally shoved out. It has been frequently observed at Santiaguito that these andesitic rocks "freeze" quite promptly—the materials at the surface must await subsequent development of pressure before they can be extruded. The porous character of the cold rock and the presence of large cavities lend support to the view that gases are released from the lava in the lower portion of the lava column. It is not to be inferred, however, that this relatively quiet effusion of material will persist. In 1929, seven years after the first appearance of the dome, a violent eruption took place which ejected and deposited on the slope below an amount of fragmental

material that has been estimated at three million cubic meters. There appears to be good reason for believing that the intensity and magnitude of the eruptions at Santiaguito are dependent on the amount of potentially active material that has worked its way toward the surface of the dome.

The work carried out during the past year has demonstrated that it is worth while to continue these studies of volcanic activity and that it would be desirable to install instruments that will yield continuous records of the seismic, electrical, and other physical changes that take place.

Pressure and the Curie point of spinels. The source of the Earth's magnetism is one of the most important problems of geophysics still awaiting solution. We especially need to know whether under the conditions of pressure and temperature within the Earth it is possible for the common magnetic materials to retain their magnetism. A promising method of attack on this problem is the investigation of the effect of high pressure on the Curie point, that is, the temperature at which the material becomes nonmagnetic. Some time ago, a study was undertaken of the relation between Curie point and composition in various ferromagnetic spinels. For one of them, which has a Curie point close to room temperature, a few measurements of magnetic susceptibility under compression indicate a noticeable difference between the compressed and uncompressed material. In order to investigate more thoroughly the effect of pressure on magnetism, an experimental set-up adapted for a large range of controlled pressures is being developed [Posnjak, Goranson] in collaboration with the Department of Terrestrial Magnetism [E. A. Johnson].

SUMMARY OF PUBLISHED WORK

- (991) An adventure in scientific collaboration. Arthur L. Day. Reprinted from *Cooperation in research*, Carnegie Inst. Wash. Pub. No. 501, pp. 3-35 (1938).

This paper contains an account of some research activities in which during past years the Carnegie Institution of Washington has cooperated with other agencies. Special attention is given to the development and management of the extensive program for seismologic studies in southern California.

- (992) The significance of pressure and of volume in geophysical investigations. L. H. Adams. Reprinted from *Cooperation in research*, Carnegie Inst. Wash. Pub. No. 501, pp. 37-47 (1938).

In the Earth both temperature and pressure increase steadily from the surface downward. An understanding of the formation of rocks under conditions that exist within the Earth requires detailed investigations of the influence of pressure on the properties and behavior of rocks. In this paper there is given a brief discussion of the interrelation of the three factors, pressure, temperature, and composition. The importance of volume in relation to pressure is emphasized, and it is concluded that space, extension, or volume is the oldest, the simplest, and the most fundamental of physical attributes. In experimental science volume is a quantity that occupies a unique position, while pressure stands out as the agent by which volume can be most effectively altered. The intrinsic interest and wide applicability of further information on volume changes under pressure deserve more general recognition.

- (993) Water in geological processes. George W. Morey. Reprinted from *Cooperation in research*, Carnegie Inst. Wash. Pub. No. 501, pp. 49-58 (1938).

A brief discussion of the occurrence of water in rock magmas, and the effect of water in the various stages of magmatic differentiation, in volcanism, and in the formation and consolidation of sedimentary deposits; and of the experimental study of silicate systems containing water at high temperatures and pressures.

- (994) The surface of the moon. F. E. Wright. Reprinted from *Cooperation in research*, Carnegie Inst. Wash. Pub. No. 501, pp. 59-74 (1938).

Report of progress of work by the Committee on Study of the Surface Features of the Moon, with emphasis on the major results thus far obtained and on the meaning and value of cooperation in research in science as illustrated by the effective attack by this committee on the problem. A brief description is given of the methods employed in study of the nature of lunar surface materials and of the data of measurement obtained through their application. The several methods are: a visual method based on the use of a special polarization eyepiece; two photoelectric methods, the first employing direct current, and the second, alternating current; a quartz polarization spectrograph; and a thermoelement method. The visual method has been used through 11 lunations and the percentage polarization of 24 selected areas on the moon ascertained at different phases of the moon. In addition, the percentage polarization of sunlight reflected by different terrestrial materials at different phase angles has been measured. The results of visual measurements indicate that lunar surface substances are of the nature of volcanic ashes and pumice high in silica. Mention is made of a method developed for the production of a photographic map of the moon and of the progress made toward realization of the series of final photographic maps. A new method is described for ascertaining the shapes and dimensions of lunar surface features from study of a series of photographs taken at short intervals of time during a complete lunation. The results of statistical studies on the frequency distribution of lunar craters of different sizes are referred to briefly, and also the ballistics of materials ejected under conditions prevailing at the moon's surface.

- (995) A statistical analysis of trends in research on the Raman effect. James H. Hibben. Proc. Indian Acad. Sci., vol. 8 (Raman Jubilee Volume), pp. 294-300 (1938).

This publication is a statistical survey of all the published work on the Raman effect that has appeared during the ten-year period since its discovery. The number of papers as a function of time, geographic distribution, and context is given. It is shown that the publication rate increased rapidly from 1928

to 1931 but decreased in 1933. This is followed by a compensatory increase, and in 1936 the rate levels off at a constant amount corresponding to approximately 220 papers a year. The diminution in 1933 represents a transition period when the research emphasis changed from the more or less purely theoretical to the practical applications. The geographical distribution of the source or origin of the research on the Raman effect indicates that the greatest amount of research is carried out in the British Empire, chiefly in India. The United States ranks third. The interest in the Raman spectra of particular types of organic and inorganic compounds is evaluated and the reasons for the preferential treatment of certain classes of compounds are discussed.

- (996) Note on the temperature attained in a burning coal seam. L. F. Brady and J. W. Greig. *Amer. Jour. Sci.*, vol. 237, pp. 116-119 (1939).

A brief description is given of the occurrence of a traplike "rock" formed by the melting of shale by a burning coal seam. Melting experiments showed that the temperature had probably been in excess of 1212° and certainly in excess of 1137°.

- (997) The hot-spring problem. Arthur L. Day. *Bull. Geol. Soc. Amer.*, vol. 50, pp. 317-336 (1939).

This address of the retiring president of the Geological Society of America contains a review and discussion of certain problems relating to hot springs and geysers. Various observations, especially those made by the author and his collaborators, lead to a partial explanation of the mechanism of thermal springs, but a definitely final solution of the problems involved has not yet been obtained.

- (998) Pressure-volume-temperature relations in solutions. I: Observations on the behavior of solutions of benzene and some of its derivatives. R. E. Gibson and O. H. Loeffler. *Jour. Phys. Chem.*, vol. 43, pp. 207-217 (1939).

The material in this paper was presented at the Symposium on Intermolecular Action held under the auspices of the Division of Physical and Inorganic Chemistry of the American Chemical Society, December 1938. A preliminary account is given of a new phase of the systematic investigation of the behavior of solutions under high pressure,

namely, the study of simultaneous pressure and temperature changes. New measurements of the compressions and thermal expansions of some derivatives of benzene (chlorobenzene, bromobenzene, nitrobenzene, and aniline) and of the specific volumes, compressions, and thermal expansions of solutions of these derivatives in benzene have confirmed and extended the empirical use of the Tait equation for expressing the compressibility of liquids as a function of pressure. (See report for 1937-1938, p. 123.) The exponential constant C in this equation has been found to be the same for all the liquids and solutions examined, and the internal pressure constants, B , for the pure liquids and the solutions have been correlated with the volume changes which take place when the liquids are mixed. The conclusions based on studies of salts in water concerning the interdependence of the volume changes on mixing and the net internal pressures of the components are found to hold qualitatively in these benzene solutions.

A short account is given of a new phenomenon observable in aniline-nitrobenzene solutions, namely, that the absorption of light by these solutions is significantly increased by relatively small increases of pressure.

- (999) Electrical properties of multilayers. R. W. Goranson and W. A. Zisman. *Jour. Chem. Phys.*, vol. 7, pp. 492-505 (1939).

This paper presents certain results on the electrical properties of multilayers of stearic acid and various stearates plated on insulating materials. The experimental data lead to the conclusion that the electrical charges of these multilayers arise from the adsorption of ions from the substrate on the carboxyl groups of the floating stearate monolayer. With a calcium-bearing substrate, for example, the first stage in the process is a conversion of stearic acid to calcium stearate, and this reaction is a function of the substrate pH and consequently of the degree of ionization of stearic acid. The next stage is represented by an adsorption of calcium ions on the carboxyl groups of the calcium stearate which are carried along with the monolayer in the plating process. The electrical charges of X-multilayers thus arise from volume distributions of positive adsorbed ions. The positive ions adsorbed on the floating

monolayer induced a cloud of negative ions in their neighborhood which, under certain conditions such as dependence on size and valency of the positive ions, may lead to electrically neutral and wetted films. With certain types of mixed films, that is, where the percentage of stearic acid present is appreciable, the rate at which the plating process is carried out becomes an important factor in determining whether X- or Y-type films can be built up, and for these cases fast dipping and withdrawal speeds can neutralize an existing multilayer charge. In plating X-multilayers it has been observed that after about 500 layers have been deposited, and the electrostatic repulsive field of the multilayer has thus reached a certain value, the upper portion of the submerged probe has a silvery appearance which gradually moves down the probe with increasing number of dips, and film does not adhere to the multilayer over this portion. This electrostatic repulsive field thus sets a limit to the thickness of X-multilayers on insulators. Under certain conditions the outer layer of multilayers dipped in film-free solutions overturns and adsorbs ions from the solution, resulting, in some cases, in wetted films and, in others, in an electrical charging of the multilayers.

- (1000) Arthur L. Day Volume. (Current research of Geophysical Laboratory, comprising Publications 966-988.) Amer. Jour. Sci., vol. 35-A. viii+404 pp. New Haven, Conn. (1938).

This collection of papers was published as a special volume of the *American Journal of Science*, dedicated to Arthur L. Day, Director of the Geophysical Laboratory from its founding until his retirement in 1936.

For abstracts of individual papers see report for 1937-1938.

- (1001) The rotation factor for equi-inclination Weissenberg photographs. George Tunell. Amer. Mineralogist, vol. 24, pp. 448-451 (1939).

In the analysis of atomic arrangements in crystals by means of X-rays, one of the most powerful tools is the Weissenberg X-ray goniometer. In order to be able to utilize equi-inclination Weissenberg layer-line photographs for this purpose it is necessary to know the value of the rotation factor for each diffraction spot on the photograph. Cox and Shaw had derived the relation for this factor

in the case in which the X-ray beam is perpendicular to the rotation axis of the crystal. Several reasons have been pointed out by others, however, why it is advantageous to take each Weissenberg layer-line photograph with the rotation axis of the crystal inclined to the incident X-ray beam at an angle equal to that made by the rotation axis with the reflected X-ray beams for the layer-line that is being analyzed; therefore the author has derived the relation for the rotation factor appropriate under such conditions. The method of equal inclinations proves to be superior to that of perpendicular incidence in respect to the character of this "correction" factor as in other respects previously considered. A chart has been prepared from which the value of the rotation factor for any diffraction spot on any equi-inclination Weissenberg photograph can be read off directly.

- (1002) Phase equilibrium relations in the system, $\text{Na}_2\text{SiO}_3\text{--Li}_2\text{SiO}_3$. F. C. Kracek. Jour. Amer. Chem. Soc., vol. 61, pp. 2157-2161 (1939).

The binary system $\text{Na}_2\text{SiO}_3\text{--Li}_2\text{SiO}_3$, a binary section within the ternary system $\text{Na}_2\text{O--Li}_2\text{O--SiO}_2$, contains an intermediate compound, NaLiSiO_3 , which melts incongruently at $847 \pm 1^\circ \text{C}$. The liquidus consists of two branches. One of these begins at the melting point of Na_2SiO_3 , $1089 \pm 1^\circ \text{C}$, falls to a minimum at 38.5 ± 0.2 per cent Li_2SiO_3 , $845 \pm 1^\circ \text{C}$, and then rises to its junction with the other branch at the peritectic point 39.3 ± 0.2 per cent Li_2SiO_3 , $847 \pm 1^\circ \text{C}$. The second branch of the liquidus rises from the peritectic point to the melting point of Li_2SiO_3 , $1201 \pm 1^\circ \text{C}$. The primary phases in equilibrium with the liquid are two series of solid solutions. The first series extends from Na_2SiO_3 to NaLiSiO_3 ; the second series is a limited one, and ranges in composition from 83 ± 3 to 100 per cent Li_2SiO_3 . The optical properties of the various phases have been measured, and are reproduced graphically in a diagram giving the variation of the refractive indices with the composition.

- (1003) Improved technique in micropycnometric density determination. C. J. Ksanda and H. E. Merwin. Amer. Mineralogist, vol. 24, pp. 482-484 (1939).

The technique described eliminates important errors usually present in the measurement of the height of a column of liquid

in a capillary. The uncertainties in measuring the volume of a liquid in a pycnometer are largely overcome if the pycnometer is filled just full, as determined by reflecting light from the meniscus of the filling liquid when the meniscus is flat across the top of the pycnometer. A micropycnometer made from a thick-walled capillary tube is described. The length and bore of the micropycnometer are made to suit the amount of material of the test sample. A method of filling pycnometers is described and the properties of some usable liquids are given. The method is especially convenient when a large number of density determinations are to be made.

- (1004) The origin of igneous rocks and their mineral constituents. J. F. Schairer. *Scientific Monthly*, vol. 49, pp. 142-154 (1939).

In this lecture, delivered at the Administration Building of the Carnegie Institution of Washington, the broad problems of igneous rock genesis are discussed and the nature of the laboratory experiments bearing on rock and mineral origin is briefly described.

Granites, basalts, and other igneous rocks form the framework of the crust of the Earth. All other rocks are derived from these primary materials. The evolution of the igneous rocks from molten silicate magmas is an interesting problem in physical chemistry, and depicts an important phase of Earth history. The chemical history of the Earth's crust is the chemistry of about ten rock-forming substances which combine and crystallize to form the minerals of the igneous rocks. These fundamental problems of rock genesis are studied in the laboratory by making artificial rocks at high temperatures in electric furnaces. The information that such studies yield gives knowledge of the origin of the igneous rocks and the composition of rock-forming minerals.

- (1005) The Raman effect and its chemical applications. James H. Hibben. *Amer. Chem. Soc. Monogr. Ser. No. 80*. 544 pp., 93 tables, 72 figs. New York, Reinhold Pub. Corp. (1939).

This book of twenty-nine chapters is a treatise on the Raman effect and its uses in the fields of chemistry, chemical physics, and physics. In the first two chapters the origin and nature of Raman spectra are described in simple terms. The next four chapters give

more precise treatment of the theory of the Raman effect and its relation to infrared absorption spectra and the vibrations of polyatomic molecules, and are written jointly with Professor Edward Teller.

The second part of the book, comprising fourteen chapters, is devoted to the applications of Raman spectra in the field of organic chemistry with particular reference to structural organic chemistry. It is shown how the various types of chemical linkage between atoms, the arrangement of atoms in space, the forces between them, and the magnitude of their oscillations may be determined. This information frequently aids in the determination of molecular constitution, Boltzmann distribution, lattice vibrations, specific heats, the fundamental vibrations of the molecule, and other properties of value and interest. All types of organic compounds are considered and dealt with according to their constitutional formulas.

The third part of the book (nine chapters) is concerned with the applications of Raman spectra in inorganic chemistry. All the inorganic compounds are divided into classes such as gases, halogen compounds, silicates, elements, acids, water, etc., and a careful analysis is made of their Raman spectra and of the intensities and polarizations of the Raman lines. This information is also applied to the determination of molecular constitution, and is of interest because the constitutions of many inorganic compounds are less well known than those of ordinary organic substances. The vibrations and rotations of the atoms in the inorganic compounds, their molecular symmetry, their fundamental vibrations, and other properties are discussed in detail. Particular emphasis is placed in this section on the symmetry of molecules in crystals and their behavior in solution, and on ionization processes, complex compound formation, and other items of significance in geophysics.

Finally, there is a bibliography consisting of over two thousand references, and a subject index giving the reference citations for every inorganic and organic compound so far investigated. The material in the book covers all aspects of the Raman effect from the time of its discovery until June 1939 and is the first treatise on this subject available in English.

- (1006) Pressure—volume—temperature relations in solutions. II: The energy—volume coefficients of aniline, nitrobenzene, bromobenzene, and chlorobenzene. R. E. Gibson and O. H. Loeffler. *Jour. Amer. Chem. Soc.*, vol. 61, pp. 2515-2522 (1939).

From measurements of the specific volumes at 25°, the thermal expansions, and the compressions of aniline, nitrobenzene, chlorobenzene, and bromobenzene, we have been able to compile a table of the volumes of these liquids at any temperature and pressure in the region 25 to 85° and 1 to 1000 bars. Suitable equations for computing the first and second derivatives are also given. From these data the coefficients $(\partial P/\partial T)_V$ and $(\partial E/\partial V)_T$ were computed. Our data enable us to discuss the variation of these and other thermodynamic functions with temperature at constant volume. Both $(\partial P/\partial T)_V$ and $(\partial E/\partial V)_T$ decrease as the temperature increases at constant volume. It is suggested that this effect is due to an increase in the repulsive internal pressure which follows from an increased randomness in the distribution of the molecules in the liquids at higher temperatures. The quantity $(B+P)$ in the Tait equation for the compressibility of the liquids is identified empirically as the repulsive internal pressure. It increases with temperature at constant volume and, when it is combined with the total internal pressure, an estimate of the attractive pressure is made. The attractive pressure so computed is expressible as $P_A = a'V^{-n}$ and is dependent only on the volume within the limits of our experimental error. The exponent n has the value 3 for benzene and 2.74 for the polar liquids.

A weight dilatometer of vitreous silica suitable for the rapid and precise measurements of the thermal expansions of solutions is described.

- (1007) Elastic properties of materials of the Earth's crust. L. H. Adams. Reprinted from *The internal constitution of the Earth* (ed. B. Gutenberg), pp. 71-89. New York, McGraw-Hill Book Co. (1939).

A knowledge of the elastic behavior of rocks is required for the solution of many problems in geophysics. Of especial importance is the correlation of the velocity of earthquake waves with the velocities calculated from laboratory measurements on the

elasticity of typical rocks. Such comparisons provide the simplest and most direct evidence concerning the constitution of those parts of the Earth that are inaccessible for direct observation. The present compilation is a summary of the data in this field, especial attention being given to those that are useful in connection with investigations of the Earth's interior.

- (1008) The crust of the Earth and its relation to the interior. H. S. Washington. Reprinted from *The internal constitution of the Earth* (ed. B. Gutenberg), pp. 91-123. New York, McGraw-Hill Book Co. (1939).

Much is known about the crust of the Earth and very little about the part that lies far below the surface. What information we have concerning the interior depends to a large extent on observations of the composition and physical state of the crust. Conversely, in order to comprehend fully the constitution of the crust and its relation to the Earth as a whole, one must know something of what lies beneath it, for there is good reason to believe that the crust and the interior are related genetically, so that an understanding of one must aid in an understanding of the other. A thorough treatment is given of the available information concerning the chemical composition of the crust of the Earth. The composition and the general characteristics of meteorites are also dealt with in detail, and the bearing of these facts on various geophysical subjects, such as the density of the Earth, the magnetism of the interior, and isostatic adjustment of the crust, is discussed.

- (1009) Comparison of the fabrics of inclusions and the adjacent intrusive rock. Earl Ingerson. *Amer. Mineralogist*, vol. 24, pp. 607-623 (1939).

Comparative fabric studies can supply much interesting and important information about many kinds of rocks without going into the controversial subjects of how various minerals yield to stress, or how preferred orientations of mineral grains may be developed under stress, or by differential movement. One such comparison is that between an intrusive rock and its inclusions. It should be possible to develop criteria for telling the origin of inclusions and to make interpretations concerning the history of an igneous massif from such studies.

This paper is a comparative study of three intrusions: (1) the Port Deposit complex, Maryland, which has been subjected to regional metamorphism after incorporation of its inclusions; (2) the Uncle Sam porphyry, Arizona, a shallow-seated intrusion that has not been metamorphosed after solidification; and (3) the Val Verde tonalite, California, whose inclusions are considered as probable "autoliths."

The following tentative conclusions are suggested, but it is emphasized that further studies may render the modification of some of them necessary:

1. Xenoliths in an intrusion that has not been subjected to regional metamorphism retain their original fabric, which is in general quite different from that of the host.

2. The fabrics of inclusions in an intrusion that has been subjected to regional metamorphism conform in type to that of the host, but show minor differences dependent upon the original fabrics of the inclusions.

3. Autoliths tend to have the same fabric as the main part of the intrusive rock. The degree of correspondence is variable, however, and depends upon how strong a preferred orientation has been developed at a given point while the magma is "plastic."

(1010) The splitting of mica (muscovite) for optical purposes. F. E. Wright. *Amer. Jour. Sci.*, vol. 237, pp. 736-741 (1939).

The cleavage of muscovite into thin sheets and strips, free from scratches and of uniform thickness, is not an extremely difficult task, if certain precautions are observed. Tests of various methods for this purpose have led to the adoption of a method based on the use of a special needle, of spatulas of soft wood, and of strips of mica with beveled edges and not over 4 cm wide and 10 cm long. With care and patience it is possible with this method to obtain strips of mica

suitable for use in optical instruments, of any prescribed phase angle, or thickness in excess of 1.5 microns. A convenient arrangement of the petrographic microscope is described for the accurate measurement, by means of the Friedel method, of the phase angle of a mica plate or foil.

(1011) The volcano-seismic crisis at Montserrat, 1933-1937. Frank A. Perret. *Carnegie Inst. Wash. Pub. No. 512*. xii+76 pp., 51 illustrations (1939).

This is the third of a series of monographs on the subject of volcanology written by the author as a Research Associate of the Institution, working in close cooperation with the staff of the Geophysical Laboratory. The first of these, *The Vesuvius eruption of 1906* (Carnegie Inst. Wash. Pub. No. 339), appeared in 1924, and was followed in 1935 by the monograph on *The eruption of Mt. Pelée, 1929-1932* (Carnegie Inst. Wash. Pub. No. 458). The present volume records his observations during a period of unusual volcano-seismic activity at Montserrat, to which he made twelve visits in the years 1934 to 1937. Information from other sources concerning the preliminary manifestations of 1933 is incorporated.

The volcanological history of the Lesser Antilles is given in a brief section, with a chart showing the islands of this volcanic province and the principal events of the historic period. In the section "Montserrat, the island," which contains several maps and profiles, the characteristics of the island proper are discussed. Two later chapters of the monograph are devoted to a specific examination of volcanic and seismic phenomena. The instruments that were used in the volcano-seismic studies are described separately. Photographs (all taken by the author), curves, charts, a summary and conclusions, and several notes complete the presentation.

(1012) Annual Report for 1938-1939.

DEPARTMENT OF TERRESTRIAL MAGNETISM¹

JOHN A. FLEMING, DIRECTOR
O. H. GISH, ASSISTANT DIRECTOR

SUMMARY

The Department during the report-year (July 1, 1938 to June 30, 1939) continued reduction and interpretation of accumulated data and experimental investigations in its laboratories and observatories. Its goal is the clearer understanding of terrestrial magnetism and terrestrial electricity and their correlated geophysical and cosmical phenomena. The work reported in more detail later in this report may be briefly summarized as follows:

Publications. In the course of specialized research it is essential from time to time to present a picture of progress. In this regard the Department has had a large share in the production of two important treatises which will satisfy a long-felt need in the literature of geophysics. *Geomagnetism*, by S. Chapman and J. Bartels, will be published by the Oxford University Press probably early in 1940, and *Terrestrial magnetism and electricity* (volume 8 of the "Physics of the Earth" series sponsored by the National Research Council), prepared under the editorship of J. A. Fleming by members of the staff and associates, is being printed by the McGraw-Hill Book Company for distribution in August 1939. These volumes—the former stressing the theoretical and mathematical aspects of terrestrial magnetism particularly, and the latter the practical and descriptive aspects of terrestrial magnetism and electricity—will supplement each other in an authentic exposi-

tion of the development and present status of these subjects.

Geomagnetic investigations. Major progress during the year was associated with phenomena of the magnetic field which have their origin beneath the Earth's surface and are consequently intimately connected with the main problem of the cause and origin of the general magnetic field of the Earth. Historical records, extending over a few hundred years, show great and rapid changes of that field; but the interval covered by these man-made records is short—much too short for safe extrapolation of observed changes backward. Do these observed changes represent minor fluctuations superposed on a relatively constant general magnetic field or do they indicate that this field is subject to major variations over lengthy periods of time?

The solution of this problem of secular variation is being sought through study of the paleomagnetization of rocks. Significant results were obtained from measurements on the connate magnetization of the varved Pleistocene clays left by the retreat of the last glaciation from New England. These measurements, extending over sediments representing a period of 1000 years in glacial times, indicate that the direction of the Earth's field then was not markedly different from that existing today and that secular variation was progressing at a rate similar to that disclosed by actual measurements in historic times. Results which may be obtained when more lengthy

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series of sediments have been collected and studied cannot be forecast, but their significance to geomagnetism is unquestionable.

Isoporic charts were constructed for the north and east components of secular change for the epoch 1920-1925, using Fisk's data. Tests were developed for assisting in estimating the accuracy of isoporic maps of the Earth, using line-integrals of the field of the magnetic secular variation. An approximate derivation of a worldwide representation of secular change was obtained by an equivalent isoporic magnetic shell just beneath the Earth's surface. The dissipation of energy from the Earth caused by the field of secular variation was found to be relatively much smaller than in the cases of other sources of dissipation of energy within the Earth.

An important new research undertaken concerns the relation of terrestrial magnetism to geological features. The distribution of rocks of various magnetic properties in the Earth's crust gives rise to irregularities in the magnetic field; conversely, knowledge of such irregularities frequently permits inference regarding the underlying structure. At high temperatures and ordinary pressures rocks lose their magnetic properties. For this reason volcanic regions present opportunities for study of such relations, particularly since the hot rocks are of special concern in interpretation of volcanic phenomena.

To test the effectiveness of magnetic methods as an approach to volcanological problems, the Department, in cooperation with the Geophysical Laboratory, made a magnetic survey in the region about the Santa María volcano in Guatemala. Although a complete survey was not possible, nor contemplated in the limited season available, the results obtained prove the practicability of the method. Variations in vertical in-

tensity of the magnetic field, amounting to 15 per cent of the total vertical intensity, showed high correlation with known structural features of the region.

Good progress is being made in a new analysis of the daily magnetic variations. This work is being extended to the analysis of magnetic-storm data, special attention being given to the relation between the external and internal parts of the field.

The derivation of the seasonal average characteristics of the disturbance daily variation and daily means of disturbance was continued, using the international disturbed days of the International Polar Year, 1932-1933, for various stations.

An investigation was made of the worldwide disturbance-fields of individual magnetic storms, using extensive data for four storms of the International Polar Year, 1932-1933. Mean hourly disturbance-vectors were derived for about 48 hours of each storm. The field-characteristics found for each hour of storm showed good general agreement with the previous findings of Birkeland. The main systematic mean hourly characteristics of the field were also shown to be in rough general agreement with those deduced from average characteristics of the field. Evidence was also found of important seasonal changes in the general form of the field, particularly in the polar regions. Although there is some possibility that a part of the electric currents responsible for magnetic storms flows outside the Earth's atmosphere, useful derivations were obtained of the form and intensity of these currents for the case when the currents are assumed to flow within the atmosphere. The mean hourly current-systems showed good agreement in general type with those proposed by Chapman.

Studies of the worldwide disturbance-fields of magnetic bays were continued and an investigation was made to de-

termine whether the S_D current-system of magnetic storms suggested by Chapman could arise from electromotive forces generated mainly along the auroral zone. An investigation is also under way to develop a more convenient method than the standard procedure of spherical harmonic analysis for analyzing the disturbance-field of storms and the secular variation.

Terrestrial electricity. Further information about the "supply-current," that electric "current" of unknown origin which maintains the negative charge of the Earth, was sought in a study of the electric conduction-current in the atmosphere deduced from measurements made at College (Alaska), at Watheroo (Western Australia), and at Huancayo (Peru). It is noteworthy that the only places in the world, where registrations are being made, which give a practically continuous record of the transfer of electricity from air to Earth are at observatories of the Institution, at the Tucson (Arizona) Magnetic Observatory of the U. S. Coast and Geodetic Survey—through cooperation with the Department—and at the Kew Observatory (England). The average magnitude of the total supply-current (about 1800 amperes) and the character of the variation during the day, first revealed by observations made on the later cruises of the *Carnegie*, were verified and evidence is seen that, upon completion of this study, these data will doubtless reveal some information about the annual variation of the supply-current. The anomalous type of diurnal variation of the potential-gradient at Watheroo was shown to be due to local factors which apparently do not reach high enough in the atmosphere to affect the diurnal variation of the electric conduction-current, a circumstance favorable for the use of these data for such fundamental investigations as that outlined above.

The rate of formation of small ions in a laboratory-room was found to decrease when the room was occupied and when, as a result of this condition, the concentration of condensation-nuclei increased. Mathematical tools which aid in the study of the effect of the electric field, acting in conjunction with other factors, in modifying the distribution of small ions near the Earth's surface were improved and tested.

A high correlation between the activity of electric currents in the Earth and solar activity, as measured by sun-spot-numbers, was more completely verified, and this correlation was shown to hold for month-to-month variations.

In cooperation with the Geophysical Laboratory, geoelectric phenomena in the vicinity of the volcano Santa Maria, Guatemala, were observed, as part of an intensive, coordinated study of that volcano. A most extraordinary feature appeared in the registrations of earth-potentials, namely, that the range in the variations of the potential-gradient in the Earth near the volcano, the more conspicuous of which are manifestations of the general earth-current circulation, on normal days far surpasses that in any other registrations of earth-potentials.

Good progress was made during the year on the preparation for publication of the atmospheric-electric data obtained since 1924 at the Watheroo and Huancayo observatories. These data for the years 1924-1934 are now in satisfactory form for detailed investigation and discussion.

Ionosphere. Quantitative analysis of ionospheric changes is now possible and was begun upon completion of the automatic multifrequency apparatus reported last year. Achievement of this ideal makes possible more exact calculations of resultant geomagnetic effects, of optimum conditions for radio transmission, of solar variations, and of other geo-

and east components of secular change for the epoch 1920-1925, using data given by Fisk. Tests were developed for assisting in estimating the accuracy of isoporic maps of the Earth, using line-integrals of the field of the magnetic secular variation. The line-integrals computed for the epoch 1920-1925 failed to vanish and show systematic changes in magnitude varying with the region of the Earth considered. This effect is attributed to the presence of considerable systematic as well as accidental errors in the data, and the errors in the data averaged along paths of integration were estimated to be such that the line-integrals might vanish. An approximate derivation was obtained of a worldwide representation of secular change by an equivalent isoporic magnetic shell just beneath the Earth's surface. The dissipation of energy from the Earth occasioned by the field of the secular variation was found to be relatively much smaller than in the cases of other sources of dissipation of energy within the Earth.

Secular variation and electromagnetic measurements of unmetamorphosed sediments (Johnson and McNish). An important investigation is that on secular variation of declination in New England during past geologic ages as deduced from the magnetic polarization of the varved Pleistocene clay. Such investigations are possible through perfection of the electromagnetic method developed last year, which permits for the first time the measurement of extremely weakly polarized unmetamorphosed sediments. A new and compact portable apparatus was constructed which allows the measurements to be made rapidly and accurately in any laboratory in spite of existing alternating-current fields. All residual parasitic effects in the apparatus have been eliminated.

Tests made on samples of clay from several widely separated locations showed that their absolute direction of

polarization is constant over extensive horizontal areas and that the tray-method of collection has a negligible effect upon the direction of polarization. The experimental method is thus fully developed and of proved reliability so far as the direction of declination is concerned. The results obtained from the varves collected from Connecticut have shown that a complete investigation of this unique type of deposit, not only in New England but in other parts of the world as well, would produce results of fundamental importance to an understanding of the Earth's magnetic field.

The glacial varves afford an unusually suitable geological deposit for magnetic investigations. First, they possess an exact relative chronology which is well established. They also have been preserved under approximately constant conditions of temperature and pressure and have undergone a minimum of physical and chemical change. The coercive force of the clays is very great, so that their magnetization has been preserved under a unique combination of fortunate geophysical circumstances. These facts make their investigation productive of decisive results as compared with the inconclusive evidence obtained from metamorphosed and igneous rocks.

Such deposits have been studied by geologists in New England, Scandinavia, and Argentina. In New England several series exist which are as yet unconnected. The longest is about 4000 years, while several shorter ones cover about 1000 years. In Sweden a series about 12,000 years long is available, while the Argentina series is considerably shorter. These varves all belong to the last glaciation, but older clays are also available, some as old as 200,000 years. The investigation so far has shown that the rates of change of declination in prehistoric times were of the same magnitude as those occurring since A.D. 1600. Furthermore, the direction of the com-

pass in Connecticut at the time the clays were deposited approximated north, just as it does today. The actual age of these deposits is between 10,000 and 20,000 years.

Two groups of varves have been collected and measured. One group of 200 years of the New Haven series showed an average declination of 30° west of north, while the second group of 500 years from the long Hartford series showed an average declination of 15° east of north. A third group of about 1000 years, also from the Hartford series, has been collected but not measured. None of these collections covered a long enough time either to establish or to disprove the existence of any particular cyclic variation of long period such as the ones proposed on the basis of the measurements of declination at London.

No conclusions can be drawn regarding worldwide aspects of secular variation from measurements at one location. Limitations on conclusions could be removed by an adequate collection of varves from New England, Sweden, and Argentina. The prosecution of such a research is important to terrestrial magnetism. In a limited time the data on secular variation could be extended over an almost unlimited period of time. Whether long-period magnetic cycles in declination exist or the variation is statistical, and whether or not the Earth's field has been reversed in the extensive period available, may be decided by this method of approach and thus provide facts to determine the validity of various theories of the origin of the general magnetic field and secular variation.

Measurements made on cores taken from the Atlantic Ocean bottom by Dr. C. S. Piggot of the Geophysical Laboratory open the possibility that such measurements may greatly extend the length of the time-scale. In this case, however, no absolute chronology is available, but only a very approximate estimate.

The success of magnetic measurements on these ocean-bottom cores depends upon the extent to which the measurements may be affected by the method of collection. In the case of the varves the method of collection by trays was proved to be reliable. To test the explosive method of collection, a series of cores was taken at East Windsor Hill, Connecticut, by Dr. Piggot while at the same time duplicate varves were obtained by the proved tray-method. Comparison of the two sets of varves will indicate the validity of the core-method. If the core-method produces no magnetic distortion, cores taken, for example, from the Pacific Ocean bottom will allow the delineation of declination for periods ranging up to millions of years.

It seems possible that, on a more limited scale, the intensity of the Earth's magnetic field at the time the sediments were deposited may also be determined. This would have additional bearing on the various theories concerning the Earth's permanent magnetic field.

Geomagnetism and volcanic structure. A magnetic survey was conducted in the region around the volcano Santa María in Guatemala in cooperation with the Geophysical Laboratory. The purpose of this survey was to study the magnetic effects produced by volcanic phenomena and to infer, if possible, the distribution of hot rocks in the region from the magnetic effects. Although the extent of the survey was insufficient to permit complete interpretation of the region, results of decided significance were obtained.

At such temperatures as are associated with volcanic activity, igneous rocks are above the Curie temperature and consequently their permeability is very much less than when the rocks are cold. Therefore, regions underlain by hot rocks should be marked by lower values of the vertical component of magnetic intensity than adjacent regions underlain by cold rocks. This presumption is verified by the survey—low values

of vertical intensity being encountered where steam-vents, hot springs, etc., give evidence of thermal activity in the substrata, while abnormally high values are encountered over adjacent regions.

Actual survey-operations were begun on January 24 and continued through March 31, 1939. Vertical intensity was observed with Askania field-balances at 442 individual stations, at 50 of which declination was observed with a regular CIW magnetometer and horizontal intensity with a la Cour quartz horizontal magnetometer (QHM). As far as possible the main and private roads leading into the coffee plantations were traveled in establishing the network of stations. Close to the volcano, where roads did not exist, foot and horseback trails were followed, and in a number of cases trails had to be cut through the brush to reach desirable sites. Close to the volcano stations were spaced about 500 meters apart, while at greater distances the station-spacing was increased gradually up to a maximum of 3000 meters. Closer spacing was employed when features of unusual interest were encountered. In the crater itself stations were spaced at 60 meters in an attempt to determine the depth of débris composing the crater-floor.

In addition to the magnetic survey, observations for latitude and longitude were made at a number of points near the volcano and positions of landmarks were determined by triangulation. Positions of well-defined peaks on the active portion of the volcano were located with reference to a base-line marked by stone and concrete monuments so that changes in the volcano can be accurately measured from time to time. Positions of the electrodes used in measuring the earth-currents were also tied in to this survey (see section on geoelectricity).

Although all the data have not been reduced as yet, several significant features are revealed. The general dis-

tribution of the magnetic field is closely correlated with characteristic geological features of the region. A profile of vertical intensity across the volcanic rift reveals a smoothed value at the rift several hundred gammas below the arbitrarily chosen "normal value" for a distance about 20 km, with a smoothed value nearly 1000 gammas above normal where the rift joins the Pacific slope. In crossing the rift vertical intensity fluctuates over wide ranges, but the average effects are pronounced. While definite conclusions are not yet possible, the data suggest the presence of hot material to depths of tens of kilometers at least in the volcanic rift. An unusual anomaly appears in the otherwise smooth portion of the profile over the Pacific slope. This same anomaly was picked up on three roads in the coastal region. It appears to extend in a line parallel with the general direction of the rift about 30 km toward the coast. The anomaly suggests that beneath the superficial material of the coastal plain a flow of volcanic material remains from more ancient activity. The profile further suggests that although the rift represents a single unit of volcanic activity, the separate centers of activity are independent to depths of several kilometers. While these views must be regarded as highly provisional, at least they have been derived from evidence independent of the visible surface-features.

The data obtained by the expedition are too few to permit a satisfactory application of the method of potential-analysis as developed during the preceding report-year for handling such problems, but they bolster the hope that more extensive data will admit such treatment. By such methods very definite inferences regarding the depth and extent of the underlying hot material may be reached. Consideration is being given the possibility of applying this

method of analysis to the available data subject to certain assumptions.

Effects of great pressure. One of the primary problems of terrestrial magnetism is the origin of the Earth's permanent field. Various theories and possibilities were considered and it seems that one of the most likely possibilities is that of a ferromagnetic Earth. If this is true it is most certain there must be a change of Curie point of the material of the Earth's crust with pressure. No adequate investigation of the pressure-coefficient of Curie temperature has been made, but such an investigation now seems possible because of the improved technique in experimental methods and because of new methods proposed for the production of high pressures. It is proposed that an investigation of the pressure-coefficient be made in cooperation with the Geophysical Laboratory and that the investigation include the development of a new apparatus to reach pressures of the order of 200,000 atmospheres.

COSMIC RELATIONS

Sun's magnetic field. From a study by McNish, Forbush, and Vestine of the status of the Sun's magnetic field it was concluded that in spite of the very fine original work done at the Mount Wilson Observatory, a considerable uncertainty still exists as to the reality and especially as to the limitation of the Sun's magnetic field. It seems certain that if the measurements are to be accepted at all, the radial limitation must also be accepted. This view is not clearly taken by many investigators concerned with effects of the Sun's field on cosmic rays and particles arriving at the Earth from the Sun. Therefore a reinvestigation of the Sun's general magnetic field would be helpful because of its important bearing on many terrestrial-magnetic problems. These considerations raise a question as to the possibility of ascertaining the

nature of the particles causing geomagnetic effects. A method of attack may be found in a proposed experiment to measure shot-effect and flicker-effect of such particles with an apparatus consisting of coils and amplifiers in conjunction with magnetometer and induction-loop records.

Cosmic-radiation relations. Forbush extended the analysis of the worldwide effect at different stations. Besides the interest in the phenomenon itself, the effect also provides a check on the stability of instruments at different stations, having indicated a defect in operation at Huancayo which would otherwise have escaped detection. It was also found that the cosmic-ray intensity is practically always lower for the five international magnetically disturbed days than for the five international magnetically quiet days of each month. This indicates that on the average the cosmic-ray intensity is lowered on days of magnetic disturbance, which is in accord with the magnetic-storm effect. It was shown that the 13.5-day and 27-day waves in cosmic-ray intensity are closely associated with those for character-figure and magnetic horizontal intensity. Thus all evidence indicates that, apart from the seasonal changes, the major changes in cosmic-ray intensity are worldwide and are due to a part of the field of magnetic disturbance, external to the Earth.

Harmonic analysis of diurnal variations for single days. The solar and lunar diurnal variations, S and L , in the horizontal component of magnetic intensity, H , at Huancayo Magnetic Observatory (Peru) are of a much higher magnitude than those recorded at any other station or in any other magnetic element. While, therefore, in the records of other observatories, S and L are mostly studied by forming averages for groups of days—for all days of an individual month, or for the quiet days

of a season, etc.—to eliminate more or less accidental fluctuations, it seemed hopeful to study in detail the changes of S and L from day to day in the Huancayo H -records in order to deduce corresponding changes in the physical state of the ionosphere as well as in the ionizing solar radiation.

The first step is to make the records, as given in hourly means, more tractable for statistical work. Harmonic analysis was used by Bartels to condense the 24 hourly means for each individual day into a small number (not more than eight) of harmonic coefficients which may be regarded as a suitable abstract of $(S+L)$. In order to deal with the great amount of material, a new scheme of computation was developed, yielding, in the most economical way, the coefficients of the periods 24, 12, 8, and 6 hours. The results were made ready for publication in a collection of tables giving harmonic coefficients for more than 5000 individual days of the years 1922 to 1937. These tables, a new feature in observatory-compilations, represent an advanced stage of reduction of the original magnetic records. It is hoped they will form a first step toward a homogeneous record giving, day by day, the fluctuations of the solar ultraviolet radiation supposed to cause the daytime ionization in the ionosphere, as a counterpart to the daily magnetic characters which record the terrestrial influence of solar corpuscular radiation.

The work done by Chapman and A. J. Majid Mian on Fourier and spherical harmonic expressions for the radiation-absorption, and the ion-content at different levels in an ideal ion-sphere, is progressing well, and is incidentally leading to some developments which probably will have a much wider bearing and importance in mathematical physics.

Lunar daily variations. Much work was done by Chapman on the computation of lunar daily variations in mag-

netic and meteorological data. This work was supported by an annual grant from the Association of Terrestrial Magnetism and Electricity of the International Union of Geodesy and Geophysics.

MAGNETIC DISTURBANCES

The derivation of the seasonal average characteristics of the disturbance daily variation and daily means of disturbance was continued, for purposes of later investigation, using international disturbed days of the International Polar Year, 1932–1933, for various stations.

Mean annual and seasonal values of the daily means of disturbance in horizontal intensity were also derived for low-latitude and middle-latitude stations by Vestine, McNish, and Cynk. The data covered the sunspot-cycle of the years 1919–1933. In conformity with a conclusion of Chapman, it was found that the average disturbance-field shown by the daily means for the horizontal-intensity component varies but little in general type during considerable ranges in the intensity of disturbance. The storm-field in horizontal intensity averaged for the year was found to be smaller in magnitude though of very similar type to that for the equinoxes, and very nearly symmetrical about the equator; near the auroral zone this storm-field is nearly twice as great in local winter as in summer. The average horizontal-intensity component of the storm-field was analyzed into parts symmetrical and asymmetrical with respect to the equator. The asymmetrical part was found to be approximately sinusoidal with a period of one year, and having a variation in amplitude with latitude.

An investigation was made by Vestine of the worldwide disturbance-fields of individual magnetic storms, using extensive data for four storms of the International Polar Year, 1932–1933, in continuation of a study undertaken under the supervision of Chapman. Mean

hourly disturbance-vectors were derived for about 48 hours of each storm. The field-characteristics found for each hour of storm showed good general agreement with the previous findings of Birkeland, in so far as the more extensive data here used overlapped in certain areas those used by him for other years, except in the region near the center of the auroral zone. In the latter region, large persistent disturbance occurred in the tangential component of the field at the Earth's surface, whereas the accompanying changes in the vertical component tended to be much smaller. The main systematic mean hourly characteristics of the field were also shown to be in rough general agreement with those deduced from average characteristics of the field, though exhibiting considerably greater variability, especially during the transition from initial to main phase of storm. Evidence was also found of important seasonal changes in the general form of the field, particularly in the polar regions. Inside the auroral zone the storms considered showed two areas having opposed fields nearly equal in size in summer. The area accompanied by eastward-flowing auroral-zone currents tended to be considerably diminished in relative extent and intensity in winter. A possible interpretation is that the average currents flowing westward along the auroral zone and in the atmosphere are relatively more intense in winter than in summer, as compared with the half-ring currents giving rise to the disturbance daily variation.

Although there is some possibility that a part of the electric currents responsible for magnetic storms flow outside the Earth's atmosphere, useful derivations were obtained of the form and intensity of these currents for the case when the currents are assumed to flow within the atmosphere. It was assumed that the currents flowed in a thin atmospheric layer at a height estimated roughly as

150 km above the Earth. Simple approximate methods were used to obtain mean hourly estimates of the currents for a number of 2-hour intervals of the storm of May 1, 1933. Rough tentative corrections were applied for induced earth-currents.

The mean hourly current-systems showed good agreement in general type with those proposed by Chapman. The currents were analyzed to give the parts yielding the storm-time and daily disturbance-variations separately for each hour. Current-systems deduced in a similar manner for an hour of each of the storms of October 14 and December 14, 1932, and for August 5, 1933, agreed well in general with those for the storm of May 1, 1933. Current-diagrams were also constructed for the hour of maximum of the initial phase of the storms of October 14, 1932, and May 1, 1933, showing a storm-time part consisting of currents flowing from west to east around the Earth, opposite in direction to those for the main phase. In the storms considered, the polar electric currents attained estimated intensities as great as two million amperes. Data given by Corlin suggest also that the main phase of the storm of May 1, 1933, was accompanied by a decrease of about 1 per cent in cosmic-ray intensity at Abisko.

Studies of the worldwide disturbance-fields of magnetic bays were continued. Heights 150 to 200 km above the Earth were estimated for the auroral-zone currents accompanying 15 bays of the year 1932-1933, on the basis of a linear current flowing along the zone. On the basis of a ribbon-current a few degrees of latitude in width, the agreement with observation was improved when the assumed height was 100 km. The latitude of the zonal currents was found to vary from time to time to north and south of the mean latitude of the zone of maximum auroral frequency. The electric

current-system flowing in the atmosphere which could reproduce the field of bays was found to resemble a distorted form of the current-system of magnetic storms.

An analysis by McNish and Johnston of the field-changes associated with the severe magnetic storms occurring during 1938 was begun. Records obtained at twenty-four magnetic observatories distributed over the entire Earth were collected. These storms are of unusual interest because of their severity and because they were associated with various other related phenomena, such as low-latitude auroral displays and cosmic-ray effects. The investigation is greatly favored by records obtained from a temporary observatory close to the geomagnetic pole established by the MacGregor Arctic Expedition in cooperation with the Department. These records, of primary importance in separating the internal and external portions of the field, furnish complete records of the storms—an unusual accomplishment for such severe storms in polar regions. The storm of April 16, 1938, which produced a range in declination at London greater than had ever been recorded there in 90 years of registration, presents an unusual feature. The change from the positive to the negative phase of the storm as recorded at a number of observatories in low latitudes did not take place simultaneously, but appeared to be propagated around the Earth, so that on the side away from the Sun the change occurred 2 hours later than on the side toward the Sun. The rapidity of this shift from positive to negative at each observatory clearly defines the time of its occurrence and may, upon subsequent study, lead to a better understanding of the nature and location of current-systems producing storms.

An investigation was made to determine whether the current-system (S_D) of magnetic storms suggested by Chapman could arise from electromotive

forces generated mainly along the auroral zone. Calculations effected for a uniformly conducting layer in the atmosphere, assuming an electromotive force varying as the sine of the longitude along circular auroral zones, showed that the current-system so produced is of the required general type. These calculations are being extended to the case where the electrical conductivity of the spherical shell is nonuniform.

An investigation is also under way to develop a method more convenient than the standard procedure using spherical harmonic analysis for purposes of analysis of the disturbance-field of storms and the secular variation.

The cooperation between Ferraro and Chapman, on the theory of magnetic storms, was continued.

Good progress is being made by Chapman and J. Crank, research assistant, in a new analysis of the daily magnetic variations, to supersede the memoir of 1919 published in *Philosophical Transactions*. This work is also being extended to the analysis of magnetic-storm data, special attention being given to the relation between the external and internal parts of the field, with a view to the extension of the studies made by Whitehead, Price, Lahiri, and Chapman on electromagnetic induction within the Earth.

MAGNETIC ACTIVITY

Magnetic character-figures for years before 1890 (Bartels). S. Chapman proposed in 1935 that the scheme for international classification of Greenwich days according to their magnetic activity, which began in 1906, should be extended backward to the early days of magnetic observatories. In reply to circular letters sent out from De Bilt, a number of observatories (increasing from 11 in 1890 to 26 in 1905) sent tables, which were used by G. van Dijk to prepare lists of daily international character-figures for

the years 1890 to 1905. Before 1890, two difficulties arose: The scale for character-figures assigned at each single station was 0 to 7, instead of 0, 1, 2 as adopted from 1890, and the number of observatories was under 10, so that the average character-figure from such small numbers might be too much affected by individual features of single stations. G. van Dijk had collected the material of 9 stations for the years 1884 to 1889, and had selected the five quiet and the five disturbed days for each month; he had also found that the annual mean character-figures for 1884 to 1889 (on the scale 0 to 7), divided by 3, came well into line with the annual mean character-figures for the years from 1890, which had already been derived on the scale 0 to 2. Bartels, as a member of the Sub-Commission of the Association of Terrestrial Magnetism and Atmospheric Electricity formed to consider this work, offered to study the question of how to compute *daily* average character-figures for 1884 to 1889. On the basis of the material which G. van Dijk readily supplied, Bartels proposed a method which might be called the "æsimilation of frequency-distributions." By twofold application of this method, first to each individual station in order to arrive at "normalized" character-figures, and then to the sum of these figures, tables were derived of daily average character-figures for 1884 to 1889 which, in the relative frequency of figures 0.0, 0.1, . . . , 2.0, resemble those for the years 1906 to 1933; they exhibit clearly 27-day recurrence-sequences. It seems possible to extend, by this method, the series of character-figures backward to 1869 and so to complete a 70-year history of the effect of solar corpuscular radiation on the Earth. This unbroken record should be of fundamental value for the discussion of solar and terrestrial relationships.

Three-hourly character-figures for

magnetic disturbances (Bartels). The experience gained in 1938 with the Potsdam magnetic "Kennziffer" (K) determined from the Niemegk magnetograms, mentioned in last year's report, was summarized by Bartels. It seems that the choice of the length of the interval (3 hours) and of the first figure, K_1 , indicating the amplitudes, is quite satisfactory and could be recommended for other observatories, if the scale for K_1 were chosen so that the frequency-distributions of K_1 at each station "assimilate" that which has proved adequate for the Niemegk records. Further discussion seems, however, necessary with respect to the second figure, K_2 , indicating the form of the variations, especially because the term "pulsations" is only vaguely defined and comprises a variety of rather different fluctuations. But even in their present form, the "Kennziffern" have been found useful in summarizing geomagnetic conditions for comparison with direct ionospheric exploration and with cosmic-ray records.

ARCHIVES OF MAGNETIC RECORDS

Miniature film-records of magnetic traces made during the Second International Polar Year on file at the Department are continuing to accumulate. So far, over a thousand such records have been received from the Central Bureau of the Polar Year Commission at Copenhagen, Denmark. In general each film contains one month of daily records from one observatory. Miniature film-records of the tabulated hourly values of the magnetic elements at the various observatories have been received and found quite satisfactory. Access to these files has been of great assistance to a number of research-projects under way.

INSTRUMENTAL DEVELOPMENTS

Electromagnetic method. The construction of the new CIW electromag-

netic primary standard proceeded as rapidly as available time in the instrument-shop would permit. The dimensions of the secondary coil were measured and the measurements on the primary are in progress. Castings for the complete magnetometer were received. The precision established in this standard will make it of great importance and, it is hoped, will stimulate the final formal adoption of an international standard. This is much to be desired if worldwide accuracy in magnetic measurements is to be attained. The theory of this new primary standard was developed taking into account all the possible kinds of corrections to parts in 10,000,000, and was published in the *Journal of Terrestrial Magnetism and Atmospheric Electricity*.

In an extension of the method used in the new primary standard, a new traveling electromagnetic standard was designed which has the same versatility as the primary standard but a somewhat lower absolute accuracy. It is designed to be a portable instrument for the measurement of horizontal intensity, vertical intensity, declination, inclination, and

total intensity, by which a measurement can be made in a few minutes with an absolute accuracy of approximately 1 part in 20,000. The entire apparatus is to be carried in two standard CIW field-cases. The material for a first model is on hand, with the exception of current-measuring equipment.

An appreciable improvement in the sensitivity and astaticism of the CIW astatic galvanometer was made by substituting an Alnico magnet-system for the carbon-steel system previously employed.

CIW induction-variometer. Satisfactory operation of the CIW induction-variometer was continued through the report-year by the staff of the Cheltenham Magnetic Observatory of the U. S. Coast and Geodetic Survey. Thus by over three years of continuous operation its practicability as a regular observatory recording-instrument has been demonstrated.

Publications. A complete list of papers during the year bearing on geomagnetic researches is given in the bibliography of publications.

TERRESTRIAL ELECTRICITY

Terrestrial electricity comprises the electric phenomena and properties of the atmosphere (atmospheric electricity) and of the Earth (geolectricity).

ATMOSPHERIC ELECTRICITY

Since a considerable part of the atmospheric-electric work during this report-year was in continuation of researches previously reported, the statement in the introduction to last year's report on this subject regarding the interrelation between its different phases and the bearing of each phase upon the broader problems is applicable here. It was pointed out there that in order to neutralize the positive electricity which

flows continuously from the atmosphere to the Earth, it is necessary that negative electricity be supplied to the Earth at the same average rate as positive electricity, namely, about 1800 amperes. This "supply-current" is doubtless the mainspring for the principal atmospheric-electric phenomena in all areas on the Earth where fair weather prevails. It is from observations of the other electric phenomena, particularly the electric conduction-current, that the magnitude and some variations of the supply-current have been deduced. The character of the variation during the day, first revealed by observations of potential-gradient and air-conductivity made at sea on cruises IV, V,

and VI and verified on cruise VII of the *Carnegie*, provided one of the principal sources of support for the hypothesis that the supply-current is generated in areas where electric storms are in progress. For further investigation of this hypothesis, one would like to have data which are adequate to show whether the supply-current varies during the year and from year to year. Such information would also be of interest for its bearing on world meteorology, because the variations in the supply-current would doubtless be closely correlated with the integrated thunderstorm activity for the whole Earth, provided this hypothesis is valid.

If the electrical properties of the atmosphere varied only with altitude, so that the vertical column of the atmosphere at one place were just like that at any other place on the Earth, then the magnitude of the supply-current and its variations could be ascertained from measurements of the transfer of electricity between air and Earth, made at a single place. But the departures from this ideal are great, particularly at some places on land. At sea, however, there is a closer approach to the ideal, and that is why it is so desirable to carry out there a program of observations like that which was being developed on the later cruises of the *Carnegie*.

Because of the complex circumstances found at stations on land, it is necessary to accumulate and analyze long series of observations of the electrical and auxiliary phenomena, from a number of well-chosen and well-distributed stations, in order to derive further reliable information about the supply-current.

The progress made in the pursuit of this objective during the report-year may be classified as follows: (a) observation of electric phenomena and properties of the atmosphere; (b) preparation for publication of an adequate quantitative description of the observations; and

(c) analysis and interpretation. The following persons gave at least part time to this section of the work: Gish, Sherman, Torreson, and Wait.

Most of the *observational work* is done at the observatories and is reported elsewhere, but the continuous registration at Washington, D. C., of the concentration of large, intermediate, and small ions in the air of an office-room was continued by Wait and Torreson during part of the year. The scrutiny of the records and reports received from the observatories with a view to insuring a high standard of reliability was made by those engaged in this section of work.

The preparation for publication of compilations of data obtained at Watheroo and at Huancayo, from the continuous registrations of the three electric elements—potential-gradient, positive conductivity, and negative conductivity—together with certain observations of meteorological conditions, required most of the time of Wait and Torreson. The progress in that work is described in the report for observatories. In the planning of these compilations, effort was made to anticipate the needs for quantitative data in future investigations, especially such as require data covering a considerable period of years and from a wide distribution of places. For example, the important question “Does the supply-current vary during the year and from year to year?” is one for which it is now evident that more such data are needed to provide a definite answer.

The analysis and interpretative investigations in progress are as follows:

The electric conduction-current in the atmosphere at College, Alaska (Gish and Sherman). Numerical values of the atmospheric-electric conduction-current were derived from registrations of potential-gradient and of both positive and negative air-conductivity obtained at College (Alaska) from October 1932 to

September 1933, by forming the product of potential-gradient and total conductivity for each hour of this period. It was found necessary to derive the individual hourly values, rather than follow the shorter approximate method of taking the product of the over-all averages of potential-gradient and conductivity, because for portions of these data, for which the two methods were compared, the approximate method gave values for the means which exceeded the means of values obtained by the more precise method by 30 per cent of the latter. Examinations of data from some other places showed a disparity, arising from that source, as great as 50 per cent. This disparity depends upon the coefficient of linear correlation between potential-gradient and conductivity in such a way that, since that coefficient is negative for data obtained at most stations on land, the approximate values are generally too great. Some published results are erroneous because of this.

This study shows that the average air-earth electric conduction-current for this period was 10.0×10^{-7} esu, almost exactly the mean obtained from measurements made on the *Carnegie*. The mean diurnal variation also closely resembles that found at sea. These results may be taken to indicate that the atmosphere over College, up to an altitude of several kilometers, is doubtless very similar to that at sea in respect to its over-all electrical properties, and that accordingly the characteristics of the conduction-current there may correspond rather well to those of the supply-current. While this statement doubtless applies in respect to the average value and the diurnal variation, one can only tentatively regard the annual variation of the conduction-current at College as a counterpart of the annual variation in the supply-current. The annual variation appears to have a double period with primary maximum in October, secondary maximum in

March, primary minimum in July, and secondary minimum in February. According to seasons, the largest values occur at the time of the equinoxes, the lowest in summer, and intermediate values in winter.

Analysis of atmospheric-electric data from Watheroo, Australia, and from Huancayo, Peru (Wait and Torreson). The following summaries cover results from analyses of atmospheric-electric data at the Watheroo and Huancayo magnetic observatories for the 11 years from 1924 to 1934.

1. Authenticity of Watheroo winter potential-gradient records: The diurnal curve for potential-gradient in winter (June to September) at Watheroo is each year consistently different from that for summer and of such character as to suggest that insulation-leak might be the cause of the unusual features in winter. This suggestion follows from the fact that the rainfall at Watheroo is largely confined to the winter, and mists and fogs at night and in the early morning are fairly frequent. Air-earth current diurnal curves for both seasons were derived from records of potential-gradient and conductivity; values from the latter were then divided into corresponding values for potential-gradient over the ocean, on the assumption that conductivity over the ocean does not vary and also that the total potential between the Earth and the ionosphere is the same over the oceans and Watheroo, to give diurnal curves for total resistance of the column of air over the station. For both summer and winter the resistance-curves were found to be very similar; therefore the authenticity of the diurnal curve of potential-gradient in winter, though unusual, is strongly supported. Analyses of total resistance at a few other stations—including Huancayo, Tucson, and Washington—for the same periods as at Watheroo showed differences to exist in the diurnal variation of

air-resistance at these stations, probably owing to local factors which must be more fully investigated. The values of total resistance, on the average, were roughly the same for Huancayo as for Watheroo, these two being in turn the same as the total resistance over the oceans; the total resistance at Tucson and at Washington was about two times and three times as great as that over the oceans, respectively.

2. Analysis of Huancayo atmospheric-electric data and study of meteorological effects: Study of records of potential-gradient and conductivity at Huancayo for the period June 1934 to December 1936 showed interesting relationships between frequency of rainfall, concentration of nuclei, and value of air-earth current. Nuclei are more numerous in dry than in rainy months, while the air-earth current is smallest in the months of highest nuclei-concentration.

3. Analysis of Watheroo and Huancayo atmospheric-electric data and study of meteorological effects: Analyses of records of potential-gradient and conductivity for March in the ten years from 1924 to 1933 at Watheroo showed conspicuous smoke-effects for two out of every three days in March in each year; the potential-gradient was high and the conductivity was low on smoky days as compared with non-smoky days. However, it was found that the low conductivity counterbalanced the high potential-gradient, for the computed values of air-earth current were the same for smoky as for non-smoky days. It was concluded that the smoke, on the smoky days, was confined to a relatively thin layer at the Earth's surface, not of sufficient extent vertically to affect significantly the total resistance of the air-column over the station. For Huancayo, twelve years' data (1925-1936) of potential-gradient and conductivity for the hour 8 to 9 A.M. daily were utilized to derive air-earth current values; monthly

means of these values were found to vary directly as the number of days per month on which rain fell. Condensation-nuclei for the years 1932-1936 were found to vary in number inversely as the number of days on which rain fell. One must conclude that nuclei, accumulating through the dry months, exist to considerable heights in the atmosphere at Huancayo and in sufficient numbers at those heights significantly to increase the total resistance of the air-column over the station and so to reduce the air-earth current, whereas in the rainy season, with rain nearly every day, nuclei are washed out and kept to low concentrations, the total resistance is lowered, and the air-earth current is increased.

4. Analysis of a group of "quiet" days of atmospheric-electric data at Huancayo in May 1934: Fourteen consecutive days of undisturbed recordings of potential-gradient and conductivity at Huancayo in May 1934 were utilized to obtain, hour by hour, 14 diurnal curves for air-earth current. The mean curve for the group, studied in relation to absolute humidity, relative humidity, temperature, and wind-velocity, showed little relation except with absolute humidity, and here the inverse relation noted was very marked. This inverse relation was definitely found also between daily means for the 14 days for current and absolute humidity. It seems best explained as an indirect relation, for at times of high humidity large ions and nuclei probably take on more moisture and grow larger than at times of low absolute humidity and become more efficient in attaching to themselves small ions, thereby reducing conductivity and increasing resistance. The process must, of course, be going on to a sufficient height above the Earth appreciably to increase the total resistance of the air-column at the station, in which case the air-earth current will be low when the

absolute humidity is high, and vice versa, as was found for the data just mentioned. This hypothesis, it will be noted, gives much importance to size, concentration, and distribution of nuclei and large ions in the atmosphere, matters about which only the most meager data are as yet available.

Effect of wind upon atmospheric-electric phenomena (Sherman). Analyses of the registration of potential-gradient and of negative conductivity obtained on the deck of the main building at Washington, D. C., from 1918 to 1932, had shown that for days of high winds the daily mean of the potential-gradient was considerably smaller than that for days with little wind, whereas the conductivity showed the inverse relation. An acceptable explanation of this finding is that, as the wind-strength increases, the condensation-nuclei—which come chiefly from the city—are more widely dispersed and their concentration, at the place of observation, is diminished; as a consequence the conductivity of the air near the Earth increases and brings about a decrease of potential-gradient. Thus one might expect the diurnal variation in potential-gradient to differ either in character or in amplitude or both, on days that differ in wind-strength. Marked differences of this character have been found at several other places, but the results of an investigation of the Washington data, now in progress, show no marked, if any, effect of that character.

Ionic equilibrium is a subject with which investigators of atmospheric electricity are much concerned, because the mathematical expressions for equilibrium between the factors, or processes, which determine the population of the ions of several types in the atmosphere have proved of considerable value even though rather rudimentary forms of the expressions are used. However, the adequacy of these expressions for some

quantitative purposes comes into question from time to time. Also lack of knowledge about the manner in which the coefficients which occur in them depend upon temperature, pressure, etc. limits their usefulness.

In 1936 the study, by Gish and Sherman, of the air-conductivity registered on the National Geographic Society-U. S. Army Air Corps stratosphere flight showed that the coefficient, in the expression for the combination between small ions, doubtless varies more slowly with pressure (for pressures below one atmosphere) than had generally been assumed theretofore. As mentioned last year, Gardner, at the University of California, working with oxygen in the laboratory, found that this coefficient depends upon pressure in the quantitative manner indicated by Gish and Sherman for the range of pressures with which they were concerned. During the past year this conclusion was again confirmed by J. Sayers, working with air at the Cavendish Laboratory. These results confirm the empirical relation first found by Gish and Sherman for the dependence of this coefficient upon pressure for pressures ranging from about 400 to 50 mm of mercury. However, there is no well-established expression for the dependence of the other coefficients, namely, those in the expressions for combination of small ions with large ions and with uncharged nuclei, upon temperature and pressure. This seriously handicaps investigation of some atmospheric-electric phenomena at higher altitudes.

As part of a study of the effect of meteorological and other factors in atmospheric-electric phenomena at Huancaayo, Torreson, using a theoretical expression advanced by F. J. W. Whipple and H. L. Wright for the coefficients of combination between small ions and large ions and uncharged nuclei, made estimates of the coefficients and of their radii. His results may be taken to indi-

cate that the coefficients, as well as the radii of the nuclei, decrease as the concentration of nuclei increases. Thus, for concentrations of 1000 per cubic centimeter the value for the average radius (12×10^{-6} cm) is ten times that found (1.2×10^{-6} cm) for a nuclei-concentration of 110,000 per cubic centimeter. Many of the nuclei in the former group should be observable in the microscope. These remarkable results stimulate interest in further investigations of these entities and of the factors which modify them. Near the close of the year Gish began an examination of an alternative interpretation of the same data; this is not complete, but one conclusion can be reported, as follows:

According to Whipple's theory, the coefficient of combination between small ions and large ions should increase when the pressure decreases. Hence, if that theory is valid, one would expect that values of that coefficient derived from the data obtained at Huancayo, which is 11,000 feet above sea-level, would tend to be greater than values derived from data obtained near sea-level. This would not appear in Torreson's estimates, because he, being unwilling to accept that phase of the theory, neglected the pressure-factor. However, when the pressure-factor is used, estimated values of the coefficients are unfavorable for Whipple's theory, because those obtained from a preponderance of the observations tend to be less, instead of greater, than values found at stations near sea-level.

Theoretical considerations, by Gish, show that the concentration of condensation-nuclei increases with altitude in the first meter or so from the Earth's surface, when the major part of the nuclei comes to a station from a distant source and when these are distributed downward chiefly by the mixing process or eddy-diffusion. It was found that the quantitative character of this distribu-

tion can be such that, taking also into consideration the electrode-effect, one can account for the observation, at the Kew Observatory, that the positive conductivity very near the surface is about twice the value at an altitude of 1 meter. In view of the small concentration of ions at Kew, this also serves as an explanation of the failure to find a decrease of potential-gradient from the surface up to several meters.

This consideration also emphasizes the importance of making measurements of nuclei and ionic concentration (or air-conductivity) at the same level in the atmosphere, if these are to be used to test the relations for ionic equilibrium and for evaluating the coefficients in those relations. Furthermore, the rate of eddy-diffusion and the electrode-effect should be further investigated in some cases where an apparent dependence of the coefficient upon other factors, such as the concentration of nuclei, is indicated.

The part played by the electric field in the ionic equilibrium in the atmosphere near the Earth's surface (electrode-effect), assuming that mixing or eddy-diffusion is negligible, was given further study by Sherman; he developed formulas from which it is possible to estimate the concentration of nuclei and the rate of formation of small ions from observed data for potential-gradient and air-conductivity. When these and other relations are applied to the data obtained at College, Alaska, during the winter of 1932-1933, the results seem satisfactorily to check the theory.

Experimental work (Wait and Torreson). The ion-counters (arranged to measure concentration of small, intermediate, and large ions) were maintained in operation in a room of the laboratory of the Department from July 1, 1938 to January 21, 1939, and at intervals in May and June 1939. Thin-walled ionization-chamber 1 was operated simultaneously with the counters

at all times. Doors and windows were kept closed until January 21, 1939, and the records of ion-content showed, as in the previous report-year, the effect of occupancy of the building, but no analyses of the records were attempted. The records of ionization, or rate of small-ion production, continued to show effect of occupancy; the ionization was low at times of occupancy when large ions (charged condensation-nuclei) were numerous. The small ions are produced in air by the action of cosmic rays, which account for about 20 per cent; by the action of radiations from radioactive matter in the soil, which account for about 30 per cent; and by radiations from radioactive decay-products in the air, which account for the remaining 50 per cent. Indoors, radiations from radioactive matter in the walls, floor, fittings, etc. of the room take the place of radiations from the soil, and the relative proportions of the three ion-producing agencies are not necessarily the same as outdoors. It is inconceivable that the ionization due to cosmic rays should in any manner be diminished through the presence of large ions in the air of a room, and it seems necessary, therefore, to account for the diminution in total ionization as an effect of large ions on the radiations from radioactive matter in the floor, walls, etc., or on radiations from decay-products in the air. In this connection, it was suggested that the diminution might be due to some of the large ions' falling to the floor, carrying radioactive matter collected by them out of the range of the ionization-apparatus. Examination of records from the small-ion and large-ion counters in conjunction with records from the ionization-apparatus indicated that some other mechanism must be operative. However, it seemed important to make further tests using only the ionization-apparatus. A wide rim or flange was attached around the base of the cellophane-walled cham-

ber of the apparatus, to catch any large ions that might fall through the air in the cylinder of air above the flange; any radioactive material brought down onto the flange by the large ions would continue to be effective in producing small ions inside the chamber, in which case the rate of production as recorded by the apparatus should not diminish with an increase in the number of large ions. This experiment is under way.

Ionization of ozone bearing on radio fade-outs accompanying chromospheric eruptions (Wait and Torreson). Radio fade-outs accompanying bright chromospheric eruptions appear to be due to increased ionization in the atmosphere in the region between 60 and 100 km, below the *E*-region of the ionosphere. It appears possible that ozone, which is present between these levels, may be decomposed through the absorption of ultraviolet light from the eruption and that ionization accompanies such decomposition. Preliminary tests on ionization accompanying decomposition of ozone were reported last year; these showed that ultraviolet light from a quartz mercury lamp gives rise to small molecular ions and to large ions as well. Further tests have now been made, to arrive at a better understanding of the underlying cause of large-ion production by ultraviolet light. With the quartz mercury arc lamp in operation, the air was found to have a negative space-charge which indicates that photo-electrons are ejected from solid matter by the light. The combination of photo-electrons with positive ions will reduce the number of positive ions present, nevertheless the number of positive ions of all classes as well as the number of negative ions of all classes is increased by the operation of the lamp; therefore the lamp seems responsible for the production of large ions. It is probable that the large ions arise as a secondary process, either by the

association of ozone, formed by the light, with water-vapor of the atmosphere, or through the growth of small ions formed by the light of these short wave-lengths. To test the latter possibility, a divided electrode-system was used with the small ion-counter to observe the growth of small ions during small intervals of time, ranging from a few hundredths of a second to several seconds. Results indicate that the small ions, when first formed, have the same mass whether produced through the action of ultraviolet light or by radioactive matter, the latter being used in comparative tests. There was no observable increase in mass during the first few seconds in the case of negative small ions formed by radioactive matter. Small negative ions formed by ultraviolet light, on the other hand, appear to increase in mass during the first few seconds, but not sufficiently to make them large ions. Therefore the production of large ions by ultraviolet light from the lamp cannot be accounted for by the growth of small ions. Whether large ions arise as a secondary process, such as the association of ozone, produced by ultraviolet light, with water-vapor of the atmosphere is now being investigated.

Electrical phenomena associated with the evaporation and condensation of water. Dr. Ross Gunn, Research Associate, undertook an experimental study of the electrical phenomena associated with the evaporation and condensation of water. It was found that the effect was important only in an ionized atmosphere. The experiments appear to show that moderately rapid evaporation in an ionized atmosphere results in the evaporating surface's acquiring a positive potential of the order of 100 millivolts. Conversely, condensation produces a negative potential of approximately the same magnitude. Experimental difficulties were numerous and the matter is not yet considered to be entirely settled.

Cooperation in atmospheric-electric work of other investigators. Because of the continued interest of air-conditioning engineers in the question whether the "condition" of the air can be improved by ionization or other electrical treatment, Wait continued as a member of the Technical Advisory Committee of the American Society of Heating and Ventilating Engineers. There was no formal meeting during the year, but various discussions were conducted by correspondence.

Dr. Boleslaw Cynk, Assistant Chief of the Marine Observatory, Gdynia, Poland, studied with Gish and Sherman, during July 1938, the Department's methods and technique for atmospheric-electric observations and particularly those used in the registration of air-conductivity on the stratosphere flight of the *Explorer II*. Information about such instrumental equipment was sent upon request to the Rev. Ignacio Puig of the Consejo Nacional de Observatorios, San Miguel, Argentina. An Aitken type of nuclei-counter was lent to the New Zealand Meteorological Service for the major part of the year.

GEOELECTRICITY

Of the various independent electrical phenomena which may be detected in the Earth, two classes were investigated during the year by Gish and Rooney. One of these classes comprises rather general circulations of electricity in the Earth, which are usually referred to as earth-currents. The other class comprises more local electrical manifestations, such as electrochemical, electrokinetic, or thermoelectric phenomena.

Earth-currents are apparently manifestations of a general system of electric currents—extensive eddies—which are induced in the Earth by its rotation in a multipolar magnetic field. The latter has its origin external to the Earth and is

manifested in variations of the magnetic field at the Earth's surface.

Earth-currents. In continuation of the study of the general system of earth-currents, Rooney constructed approximate current-functions from earth-current-potential data for stations which were not included in the previous studies and for some of which data have only recently been made available through publication. These additional stations were located chiefly in or near the north frigid zone. From comparison of these current-functions with the general picture indicated by most of the data from other places, it is concluded that the earth-current eddies are considerably distorted in the region to the north of Europe. In a general way this may be expected to result from the contrast between the electrical conductivity of sea-water and that of the land-structure and from the configuration of the land-and ocean-areas of that region. Further investigation is required in order to ascertain whether this is an adequate explanation of the nonconformity or whether it is necessary to assume that contrasts in the electrical conductivity in deeper portions of the lithosphere also play a part.

The study of the correlation between earth-current activity, as indicated by the diurnal range, and solar activity, as measured by sunspot-numbers, was extended and prepared for publication by Rooney. It was found that the correlation between the mean diurnal range in earth-currents for each year and the mean annual sunspot-numbers is very high (correlation-coefficient 0.95), and that that between the mean diurnal range for each month and the corresponding mean for the sunspot-numbers, although less, is nevertheless surprisingly large when seasonal variation in the earth-current data is eliminated, the correlation-coefficient being 0.78.

Geoelectric phenomena near the vol-

cano Santa María. Through cooperation between the Geophysical Laboratory and the Department of Terrestrial Magnetism, geoelectric measurements were made in the vicinity of the volcano Santa María, near Quezaltenango, Guatemala, Central America. This was part of a program proposed by Dr. E. G. Zies for an intensive volcanological investigation, in which geophysical methods which may aid in that investigation were to be tried. Reasons for thinking that some of the Department's geoelectric methods may deserve a trial were indicated in the last annual report.

The work done in Guatemala consisted of two parts, namely, (a) potential-surveys in which the difference of potential between two points on the surface of the Earth was measured from place to place in a chosen area and in such a way that lines of equal potential could be charted for the areas, and (b) continuous registration of the difference of potential between two pairs of points on the Earth's surface. Whenever feasible, one of the pairs was selected so as to lie on a north-south line and the other so as to lie on an east-west line. These registrations provide the data needed for ascertaining the changes with time in both the intensity and the direction of the potential-gradient in the Earth.

A thorough *potential-survey* was made over the floor of the crater of Santa María. Minor reconnaissance-surveys of this type were made on the southerly slope of the dome, known as Santiaguito, around the hot springs in the general vicinity of the village of Zunil, and over other formations near Quezaltenango. So far as the discussion has gone, it can be stated that some well-marked characteristics are manifested, particularly in the survey of the crater-floor; there the most general feature in the distribution of potential is that near the active dome,

Santiaguito, the potential is generally greater than at more remote positions.

Continuous records of two components of the earth-potential gradient for 37 complete days were obtained in the vicinity of the camp on the southwest flank of Santa María, namely, on the side toward the Pacific Ocean, at an altitude of about 6500 feet above sea-level. After camp had been broken, similar registrations were made for the duration of a week at each of two other places, namely, (a) at Finca El Faro, a coffee plantation, about 6 km south-southwest of the camp and at 4000 feet lower elevation, and (b) at Finca La Floresta, in the outskirts of Quezaltenango, about 11 km to the northeast of Santa María at 8000 feet elevation.

The outstanding feature of the records obtained at these places is the large amplitude of the variations. Thus, while the general character of the diurnal variation of the earth-potential gradient at all three places is similar to that found at a number of other places on the Earth, yet at Santa María and El Faro the diurnal range (range of the graph for the mean diurnal variation) is nearly one hundred times that found at Watheroo, Western Australia, and is about three times the extraordinarily large range reported from the Ebro Observatory at Tortosa, Spain. Although the diurnal range at La Floresta is much less than at the other Guatemalan stations, it is nevertheless large relative to that found in the observations at all other places, except the Ebro Observatory, where a range of comparable magnitude is observed. Irregular variations at these Guatemalan stations also have unusually large ranges. For example, at Santa María most of the records show one or more excursions having a duration averaging about $\frac{1}{2}$ hour and a range of 100 mv/km or more. Some of these are universal instead of local phenomena, since they can also be identified in records

obtained simultaneously at the Tucson Magnetic Observatory (Arizona) and at the Huancayo Magnetic Observatory (Peru). That some of the irregular variations are of purely local origin and possibly associated with some aspects of volcanic activity at Santa María is little more than a surmise at the present stage of the study, but it is hoped that after these records have been more thoroughly analyzed and compared with the records obtained simultaneously at Tucson, Huancayo, and Watheroo it will be possible to reach a definite conclusion. However, since it has been found that the records obtained in Guatemala contain a prominent "background," provided by the general system of earth-currents, this hope may not be realized in the study of the limited data obtained on this expedition. Because of the prominent background of universal effects, it will be desirable in future work of this character to obtain simultaneous registrations at several places in the vicinity of the volcano, so that if there are geoelectric variations associated with its activity these may be more readily distinguished from the other variations by the manner in which they depend upon position.

The large range in the diurnal variation, and in other variations derived from the general system of earth-currents, is doubtless of interest for volcanology, in that it probably indicates a very high electrical resistivity of the structure to depths of some kilometers, near the volcano and on the Pacific slope, even though the overburden, as indicated by rough tests, has relatively low resistivity, whereas near Quezaltenango, in the valley of the Rio Samalá, the low-resistivity overburden apparently extends to considerable depths.

It is important to volcanology to ascertain whether there are geoelectric variations which are associated with volcanic activity, chiefly because, if such an association is found, registration of

the geoelectric variations would provide a continuous index to volcanic activity.

Publications. Gish prepared a chapter on atmospheric electricity for *Terrestrial magnetism and electricity* (volume 8 of the National Research Council's series on "Physics of the Earth"); this outlines the status of knowledge of the atmospheric phenomena of fair weather, unsolved problems, and the principal objectives of present-day research. Chapters for this volume were prepared by Torreson on atmospheric-electric instruments and by Rooney on earth-currents.

Sherman presented a paper on "Atmospheric-electric relations in quiet air" before the American Geophysical Union. Papers by Wait and Torreson included "Radioactive content of the atmosphere as affected by the presence of condensation-nuclei" before the American Physical Society, and "Some effects of meteorological disturbances on the electrical condition of the lower atmosphere" before the American Geophysical Union.

Published papers on atmospheric electricity and geoelectricity are listed in the bibliography of publications.

INVESTIGATIONS OF THE IONOSPHERE AND ITS RELATION TO TERRESTRIAL MAGNETISM

The electrified region of the outer atmosphere—the ionosphere—which extends upward above the 40-mile level, provides a productive region for physical investigation. Ion-banks of the ionosphere turn back radio waves so that reception over long distances is possible. Electrical conductivity of the ionosphere provides paths for the flow of currents which influence changes in geomagnetism. The ion-density of these regions is a sensitive indicator of the intensity of the ionizing emanations which create them and thus is a measure of radiations absorbed in the outer atmosphere which never reach the Earth's surface. Furthermore, experiments can be performed in these regions of low gas-pressure on a scale which would be impracticable at the Earth's surface.

Investigation of the ionosphere concerns primarily the nature of the outer atmosphere and the relation between effects thus discovered and associated geophysical and astrophysical phenomena. The first step was the establishment in a qualitative sense of the principal phenomena in outer atmospheric regions. This was begun at the Department in 1925, when it was shown that the height of the ionized regions could be measured directly by the now well-known "echo"-

method. In this method a short pulse of radio waves is transmitted upward, its echo from the ionosphere is observed on its return, and the measure of height is determined from the time-interval between pulse and echo. From this basic experiment has evolved the present general method of investigation.

Subsequent to the original experiments, perfection of the method permitted measurement of the distribution of ion-density through the outer atmosphere. Instead of the single ionized region originally conceived by Stewart, Schuster, Kennelly, and Heaviside, there are found two and sometimes three or more distinct ionized regions. These regions have diurnal variations in density and height, change with season, change with time along the sunspot-cycle, and are subject to marked fluctuation during magnetic storms. Occasionally violent changes, such as are associated with radio fade-outs or auroras, and other complicated effects occur, the import of which is not yet understood. Ionization of the outer atmosphere extends through such a wide range of height and of atmospheric pressure that effects at different levels are profoundly different.

The results of the earlier qualitative

experiments can be summarized by saying that they demonstrated the problem to be a meteorological one. The whole of the outer atmosphere is constantly fluctuating, from several independent causes; therefore a single or several measurements are not representative of all conditions at a particular location. A long series of observations is necessary to determine each independent factor involved in the changes and its relative importance.

To be of real utility, the investigations must yield the ionospheric fluctuations in terms of known variables in an exact quantitative way. Thus expressions for height, ion-density, and conductivity must be given in exact mathematical form in terms of factors affecting them, such as position of the observing location on the Earth's surface, declination and hour-angle of celestial bodies involved, variation of solar radiation, and other terrestrial or extra-terrestrial effects. Realization of such an ideal would make possible exact calculation of resultant geomagnetic effects, optimum conditions for radio transmission, and an understanding of a good many other things of which we are becoming aware.

This has been the basis of the Department's quantitative stage of the investigation, which was begun with the automatic multifrequency equipment at the observatories of the Department (Huan-cayo in 1937 and Watheroo in 1938). This apparatus is the culmination of several years of experiment directed toward provision of adequate quantitative data as reported in previous years. It yields automatically four complete records of the ionosphere each hour, and gives completely homogeneous information about heights and ion-densities of the various ionospheric regions and of all the changes which occur.

For quantitative analysis it is of first importance that the data be homogeneous. For an understanding of the

operative causes of ionospheric change, it is necessary that the fluctuations during each day be represented by simple mathematical expressions. Then from these the various independent effects can be isolated. The simplest and best representation, as is well demonstrated by other geophysical research, is obtained by harmonic analysis. Such analysis permits reducing the great unwieldy volume of numbers representing the heights or ion-densities for each epoch to a few simple numbers which represent these data with high precision. Harmonic analysis can be applied to uncover hidden periodicities when the data are practically homogeneous and available over a sufficiently long period. Then the smaller hidden but important periodicities can be separated from much larger and apparently overwhelming effects. Such methods, as developed and applied at the Department in the fields of meteorology and terrestrial magnetism by Bartels, and in the study of cosmic rays by Forbush, afford excellent means for delineating the facts quantitatively.

Application of such quantitative methods is dependent on a homogeneity of data such as is obtained with automatic multifrequency equipment recently developed at the Department. The Department lends every possible assistance to other organizations in initiating similar programs elsewhere. Sufficient data are now accumulated to begin analyses along these lines.

PRINCIPAL INVESTIGATIONS

Improvement of apparatus. Major attention was given the quantitative aspects of the problem. The automatic instruments in the field were adjusted to maximum efficiency and the program of operation and maintenance was standardized in anticipation of operation over at least one sunspot-cycle. The success of the program is in large part due to the thorough and extended study and

intense interest of the personnel at our observatories.

Fixed-frequency recording. Recording of virtual heights on a fixed frequency of 4.8 mc per second, which was discontinued for a few months during installation and test of the multifrequency apparatus, was resumed at the Watheroo Magnetic Observatory in addition to the multifrequency recording. The fixed frequency is recorded on an unused portion of the multifrequency trace. The fixed-frequency apparatus operates entirely from the power-supply of the multifrequency apparatus. This represents a real addition to the information available from the ionospheric records without appreciable effort and expense. Thus the long series of fixed-frequency observations is continued and an exact chronology of events, such as fade-outs and sporadic *E*-region ionization, is available across the gap between successive multifrequency records. Addition of the fixed-frequency recorder is now under way at Huancaayo.

Harmonic analysis. Harmonic analysis of the reduced data from the observatories was begun. Harmonic coefficients for individual days are determined for the 24-hour, 12-hour, 8-hour, and 6-hour waves; these represent the actual data within a good degree of approximation. The method permits calculations of "expectancy," "probable radius," and other quantities which will define statistically the reality of persistence of different observed fluctuations. At present attention is concentrated on study of the F_2 -region, the immediate objective of which is to establish quantitatively the nature of fluctuations in the F_2 -region. These are being examined for direct solar and lunar effects.

Publication of data. General dissemination of data is necessary in order to make possible study of variations over the Earth's surface. Current ionospheric results from the observatories are now

published in the scientific literature in the form of quarterly reports.

Discovery of movement of ion-banks. A new effect was discovered with the beginning of automatic recording at Watheroo. It was found that during the early morning hours—some two hours before sunrise—a bank of ions moves downward from the F_2 -region at 250 km to a level of about 140 km. This downward movement takes place in about an hour. The new layer formed decreases in ion-density, because of recombination, until sunrise, when its ion-density increases rapidly and it can be recognized as the E_2 -region. It has been known for some time that the ion-density of the F_2 -region dips anomalously just before sunrise, and a number of unproved explanations have been offered. It is now found, however, that this dip in density occurs because of the abstraction of ions from the F_2 -region. These ions are carried downward to form the new region before sunrise, thus depleting the ionization of the F_2 -region and producing the decrease of density. This is the first known case of layer-separation in absence of direct sunlight. The effect indicates the pressure of forces hitherto unsuspected in the outer atmosphere. The discovery is so recent that a detailed study has not yet been possible.

Intercomparison of F_2 critical frequencies. Simultaneous values of F_2 critical frequencies for Watheroo and Canberra (separation 1980 miles) were compared during Berkner's work at Sydney. While these showed a high correlation, there were some days which did not agree. Some days showed high critical frequency at Watheroo with a low value at Canberra, and others showed high values at Canberra with low values at Watheroo. This leads to certain important implications hitherto not recognized. Ion-density in the F_2 -region must vary from station to station by large amounts under appropriate conditions.

Thus measurements at one station on a particular day are not sufficient to give very general information on that day. This presents a new field for investigation of the cause of such effects. Recently Martyn has suggested that they may be related to local weather-conditions.

Abnormal E-region ionization. Quantitative investigation of abnormal E-region ionization was begun at Watheroo. This is unnecessary at Huancayo, on the magnetic equator, where the effect is seldom observed. The predominance of abnormal intense ionization at about 110-km height above Watheroo as compared with Huancayo was previously reported. The new investigation is to determine distribution of occurrence and intensity with time of day, with season, and from year to year; it is hoped it will yield information concerning the source of the effect.

Radio fade-outs. Investigations of the radio fade-outs associated with bright chromospheric eruptions, which are so important to problems of geomagnetism, were continued. An analysis of a number of fade-outs showed that the fade-out can be defined quantitatively as the upward extension in wave-frequency of lower absorption-limit on echo-return. This analysis failed to show any change of F_2 -region ion-density associated with fade-outs. The data from Sydney and Canberra were studied at Sydney by Berkner and Dr. D. F. Martyn of the Australian Radio Research Board. It was found that the small changes in F_2 -region ion-density associated with bright chromospheric eruptions, previously reported by Martyn and his colleagues, were not regularly coincident with fade-outs as defined above. The investigation showed that a dip of F_2 -region ion-density sometimes occurred immediately at the onset of the eruption, while the fade-out occurred at some later development or phase of the eruption. In one instance

no sign of fade-out was found until about two hours after the first evidence of the solar effect. Therefore, the two effects may be not directly associated. This further confirms the view that the geomagnetic effects associated with the bright chromospheric eruptions result from increased conductivity of the lower ionosphere, because a magnetic change of this kind is always coincident with the fade-out.

Ionospheric effects associated with magnetic disturbances. Investigations of ionospheric effects during magnetic disturbances were continued. One of the more important discoveries made at Huancayo is that during magnetic disturbance there is a material change in the ionosphere at the magnetic equator. There appear to be two principal effects in the ionosphere during magnetic disturbance, namely, (1) an expansion or "blowing up" of the F_2 - or F -region, leaving numerous scattered clouds of varying ion-density through the region in contrast with the relatively uniform homogeneous F_2 - or F -region under normal conditions, and (2) an increase in absorption of radio waves passing into the ionosphere, indicating increased ion-density of the absorbing region. During the "blow-up" process in the F_2 -region, the maximum density of ionization falls, but, because it becomes more diffuse, the total ionization may have increased. The F - or F_2 -region is not always affected. It appears that the magnetic effect extends downward into the F - or F_2 -region, the depth depending on intensity of disturbance. When F -region heights are low, as during the winter day, the effect of magnetic activity is apparent for only the more intense storms. When the region is high, as during the night or summer day, the effect is apparent for even minor disturbances. When a magnetic disturbance begins at night, its counterpart in the ionosphere is almost immediately appar-

ent. This shows that the disturbing force reaches the night side of the hemisphere.

Nonseasonal change of F_2 -region. A nonseasonal or "annual" change of F_2 -region ion-density, having the same phase at Watheroo and at Washington despite the fact that they are in opposite hemispheres, was described in the report of last year—a conclusion based on noon values only. Further investigation, extended to include the whole 24 hours at Watheroo, Washington, and Huancayo, shows clearly the presence of the "non-seasonal" variation at all three stations. It demonstrates that the effect is a general one which cannot be attributed simply to peculiarities of the first two locations analyzed or to the "bite-out" effect in midday values of ion-density. Harmonic analysis of homogeneous data will provide valuable material for further analysis.

Ionospheric change with sunspot-activity. The variation of ion-density with sunspot-activity is clearly evident with the falling trend of ion-density marked early in 1939. With the decrease of mean provisional sunspot-number from 103 during the last quarter of 1938 to 75 during the first quarter of 1939, there has been a noticeable fall in the average ion-density of all regions, most pronounced in the F_2 -region; this follows the previous finding, namely, the increase of the F_2 -region ion-density in a ratio of about 5 to 1 from sunspot-minimum to sunspot-maximum.

Lorentz polarization-correction. The value of the Lorentz polarization-correction was investigated further. Retardation of the x wave-component tending to infinity can be clearly observed at Watheroo on frequent occasions. The interpretation of these results indicates that the added contribution $(4\pi/3)\vec{P}$ should be included in the force per unit-charge exerted by an electric field on

an elementary charged particle in the medium.

Portable field-apparatus. Need for a portable type of multifrequency ionospheric apparatus has become increasingly evident during the past year. A decisive experiment concerning the Lorentz polarization-correction can be conducted at high geomagnetic latitude. There is a necessity for measurements during solar eclipses to test the recombination-theory and to give measures of conductivity at the different levels. There are now a sufficient number of fixed ionospheric stations to give adequate control-data during studies involving variable latitudes, as aboard ship. Furthermore, the theories of radio wave-propagation at oblique incidence must be tested in their relation to ionospheric measurements at vertical incidence. To make possible these experiments, design of a portable apparatus capable of fulfilling the imposed requirements was begun.

THEORETICAL INVESTIGATIONS

Dr. H. G. Booker, Research Associate, took a large part in the theoretical work on the ionosphere. He considered the ray-theory of propagation of radio waves in the ionosphere under the influence of the Earth's magnetic field in a paper developing a powerful new method of analyzing propagation of waves incident in any direction upon a non-isotropic ionosphere stratified in horizontal planes. Progress was made in the application of the new theory to the ionosphere; manageable formulas were developed for phase- and group-propagation; analytical expressions were obtained for lower and upper bounds of the critical electron-densities required for reflection. In short, means were evolved for numerical consummation of the theory in series of curves representing phase-propagation, attenuation, horizontal range, lateral deviation, and equivalent path.

A new development in propagation-theory is a method for transforming the difficult problem of the curved Earth into the problem of the flat Earth, now comparatively well understood. For propagation in an ionosphere stratified in horizontal planes methods exist which make it possible to handle turning of the ray toward or away from a fixed vertical. For propagation in an ionosphere stratified in spheres concentric with the Earth's surface it is necessary to handle in addition systematic turning of the vertical toward the ray. By re-expressing this systematic turning of the vertical toward the ray as turning of the ray toward the vertical, the problem of the curved Earth can be transformed into the problem of the flat Earth. This method of dealing with curvature of the Earth may even be applied to pure diffraction of waves around the curved surfaces of the Earth. This leads to a beautifully simple interpretation of the diffraction-theories of Eckersley and van der Pol in terms of propagation over a flat Earth in the presence of an atmosphere with a slight vertical gradient of density.

The full text of the paper by Booker and Berkner on the necessity for including the Lorentz polarization-correction in the theory of propagation in the ionosphere was published and has caused considerable comment. The authors have had opportunity to test opinion both in England and in Australia. It seems to be generally agreed that the observations cannot be interpreted in terms of the simple Sellmeyer theory. It is not so generally agreed, however, that the correction required in the simple Sellmeyer theory is inclusion of the Lorentz polarization-correction. Three alternative theories have been put forward, two (in print) by Martyn and Munro in Australia, and one (in conversation) by T. L. Eckersley in England. Martyn and Munro now agree that observations near

Sydney cannot be interpreted in terms of their first theory, or in terms of Eckersley's theory. It is understood that Martyn and Munro also agree that their second theory is inconsistent with Maxwell's electromagnetic equations. Moreover, the viewpoint of Booker and Berkner has been greatly reinforced as a result of the establishment at Watheroo, Western Australia, of automatic multifrequency equipment. Preliminary examination of records from Watheroo indicates that, although ionospheric conditions are somewhat different in Australia from what they are in the United States, nevertheless observations at Watheroo provide striking confirmation of the Lorentz theory. There is every hope that more complete examination of records from Watheroo will finally clinch the necessity of including the Lorentz polarization-correction. This will increase by 50 per cent all our estimates of maximum electron-density in ionospheric regions.

Fundamental physical principles underlying the problem of the Lorentz polarization-correction were examined some years ago by Darwin. Booker has had the opportunity of discussing with Darwin this aspect of the problem. It is a question of evaluating the average oscillatory force acting on a free electron moving in an ionized gas which is subject to an alternating electric field. The lifetime of an electron may be roughly subdivided into (1) short periods during which the electron is colliding with what may be regarded as a proton and (2) long periods during which the electron is not colliding with a proton. Darwin has established the important result that the average oscillating force acting on an electron is controlled almost entirely by what happens in the long periods between collisions. Now Darwin regards it as highly probable that the average oscillatory force acting on an electron between collisions is the Sellmeyer, not

the Lorentz, force. But Booker is doubtful of this, and regards proof of this statement as the crux of the problem. Difficulty in evaluating the average oscillatory force acting on an electron between collisions arises from coupling between the oscillatory and thermic motions of the electron.

RECORDING AND REDUCTION OF DATA

Recording of data. Nearly two years of continuous ionospheric recording by multifrequency methods were completed at Huancayo and more than a year was completed at Watheroo. The procedure of maintenance was systematized in anticipation of recording over a sunspot-cycle at our observatories. Ninety-six records of ion-distribution are obtained each day. These form effectively the cross-section of the three-dimensional picture involving height, ion-density, and time.

Tabulation and publication of data. Eight sheets of scalings from the records are prepared monthly at each observatory. These tabulate the hourly values of virtual heights and critical or penetration-frequencies for each of E -, F_1 -, and F_2 -regions, the minimum frequency on which reflections occur, the squares of F_2 critical frequencies, daily means, and hourly values of monthly means. The monthly-mean data are published in the *Journal of Terrestrial Magnetism and Atmospheric Electricity*, making the data available to all investigators at the earliest possible date.

Tabulation of abnormal E -region (110-km) ionization is made at the Watheroo Magnetic Observatory for each month; this is not required at the Huancayo Magnetic Observatory, which is on the magnetic equator and at which the effect seldom occurs. These tabulations for a few years should yield information concerning the time-distribution of this effect sufficient to determine its cause.

Radio fade-outs are tabulated at the observatories. As a result of investigation by the Department, it is now generally agreed that these are best defined quantitatively by the upward extension of the lower absorption-limit on echo-return. This quantity, as defined from both the multifrequency and the fixed-frequency records, times of maximum, of commencement, of ending, and of associated events, are entered in the tabulation. Lists of fade-outs are published at regular intervals with pertinent information for general scientific utilization.

Harmonic analysis of data. Harmonic analysis of the data is made at the Department directly from the tabulations compiled at the observatories. A 12-ordinate analysis is used and harmonic coefficients for the first four harmonics (24-, 12-, 8-, and 6-hour waves) are derived. Data are computed from which expectancies and probable radii for single vectors and for the mean vector, representing the fluctuations, can be derived. Harmonic analysis of F_2 -region virtual heights at the Watheroo Magnetic Observatory is up to date; harmonic analyses of remaining F_2 -region data from both observatories are under way.

Personnel. The program of ionospheric investigation was executed by Berkner at Watheroo and Washington, Wells at Huancayo, Booker at Washington and Cambridge, and Seaton at Washington. Supervision and maintenance of the equipment at the observatories is carried on by the observers of the regular staffs, to whom much of the successful realization of the program is due.

COOPERATIVE ENDEAVOR

The Fifth Annual Conference on Ionospheric Research was held in the library of the Department of Terrestrial Magnetism on April 29, 1939, following the close of the spring scientific meetings.

Fifty persons attended; they represent the following organizations which are interested in various phases of ionospheric research: Bell Telephone Laboratories, Bureau of Chemistry and Soils of the U. S. Department of Agriculture, Carnegie Institution of Washington, Federal Communications Commission, Gulf Research and Development Company, Harvard University, International Telephone and Telegraph Company, Jansky and Bailey, Meteorological Service of Canada, National Bureau of Standards, Division of Physics and Electrical Engineering of the National Research Council of Canada, Naval Research Laboratory, RCA Communications, Inc., Signal Corps of the U. S. Army, University of Virginia, and West Virginia University.

The agenda dealt principally with ionospheric disturbances associated with magnetic storms. Interest in these phenomena arises because of their twofold significance: practical importance to radio communication and clearer understanding of the processes taking place in the ionosphere. Current investigations relating to the source of radio fade-outs associated with bright chromospheric eruptions were reported. Better dissemination of observational data was discussed.

The Department was represented at the Science Congress, Australian and New Zealand Association for the Advancement of Science, at Canberra, January 11 to 19, 1939, by Berkner. Subsequent to this Congress he spent six weeks in collaboration with the Australian Radio Research Board. This was arranged through the courtesy of Mr. David Rivett, Secretary of the Council for Scientific and Industrial Research, and of Professor Madsen of the University of Sydney and Professor Laby of the University of Melbourne. This visit gave excellent opportunity for discussion of ionospheric results of the Department and the Board, comparison

of methods, and plans for interchange of uniform data between the organizations. In addition, laboratories of the Postmaster General's Department, Amalgamated Wireless Company, and Defence Department were visited.

In New Zealand the ionospheric and radio research of the Department of Scientific and Industrial Research was studied. In Auckland the directional and polarization work under Professor Burbidge of Auckland University College was observed. Ionospheric observations and their meteorological implications were discussed with Dr. Marsden, the late Dr. Kidson, and Dr. Barnett at Wellington. The eclipse and critical-frequency measurements of Professor Florence and Dr. Peddie were studied at Wellington University College. At Christchurch a homogeneous set of daylight ionospheric observations, extending back to 1937, was made available by Professor White of Canterbury University College. Professor White had just extended the range of observation by installation of equipment. Atmospherics-recordings taken under the direction of Professor Jack of Otago University were made available for study.

As a result of these discussions, arrangements for general interchange of hourly values are well advanced. These arrangements are being completed during the coming year so that all interested organizations in various parts of the world will make generally available their hourly data.

Publications. Lectures were given and colloquia were led by Berkner during his visits to the universities at Melbourne, Sydney, Auckland, Wellington, Christchurch, and Dunedin; these concerned aspects of ionospheric research as well as the more general work of the Department. Opportunity was taken on return to the United States to visit the Mount Wilson Observatory of the Carnegie Institution of Washington and to meet Professor Terman and Dr. Brad-

bury at Stanford University to discuss problems of solar and terrestrial relationships.

Published papers on investigations of the ionosphere are listed in the bibliography of publications.

MAGNETISM AND ATOMIC PHYSICS

THE PRIMARY STRUCTURAL FORCES OPERATING INSIDE ALL MATTER

The program of studies in the laboratory relating to the fundamental nature of magnetism concerns those forces which come into play in the simplest cases of magnetic interaction, namely, when two single primary particles of matter come close to each other. These primary massive particles, out of which all matter is constructed, are the proton (electrically positive nucleus of a hydrogen atom) and the neutron (similar to a proton but with no electrical charge). A fundamental peculiarity of Nature is that these particles both possess intrinsic magnetic moment as one of their very few individual properties. During the preceding three years much effort had been spent on the proton-proton interaction. The remarkable characteristics of the tremendous attractive forces between protons, which serve together with the proton-neutron attraction as the structural basis for the nuclei of all the chemical elements, have been described in previous reports. This past year, attention was centered on certain aspects of the proton-neutron interaction, particularly measurements of the scattering of very fast and of moderately slow neutrons by hydrogen (protons). The results are in numerical agreement with calculations made on the theory as previously used, although the discovery by Rabi and his colleagues of the electrical quadrupole moment of the nucleus of heavy hydrogen (one proton added to one neutron) makes that theory untenable or at most incomplete. Any new formulation of the theory, however, must again have the proton-proton and proton-neutron forces very nearly equal and

must lead to the same proton-neutron scattering as before at high energies (14 to 16 million volts) to agree with these experiments. Another surprising fact discovered here during the year is that the scattering cross-section of heavy hydrogen for these fast neutrons is the same as for ordinary hydrogen. Either a larger or a smaller cross-section for heavy hydrogen would have been perfectly reasonable, but the two collision-areas are surprisingly the same, at least within the limits of the best measurements which have proved feasible as yet.

THE ATOMIC-PHYSICS OBSERVATORY

The successful development of techniques and equipment which overstep the limitations previously standing in the way of certain desired observations, rather than the mental perception of new reasons for desiring certain types of observations, seems to be the chief means of progress in the physical sciences during the present period of rapid development. New experiments lead the way for new ideas; developments of a theoretical character are most frequently of a type which bring together a group of experimental facts as parts of one general notion, while the stimulus for really new notions and ideas comes nearly always from experiments which extend beyond the boundaries previously explored.

Accordingly, the completion of the new constant-potential equipment of the Atomic-Physics Observatory was pushed. By the end of September 1938 the high-voltage generator-unit of this installation, designed and constructed in every detail by our own staff, was ready for

test. After preliminary adjustment this machine reached steady potentials of about 6 million volts; above this point sparks occurred which broke the commercial antenna-insulators used for the control-rods entering the high-voltage electrode. There is no reason to believe this voltage is the ultimate limit for the machine, since these porcelain rods are an incidental part of the apparatus readily replaceable by other materials. However, 6 million volts is ample for most of the measurements which will be needed in the next several years, and, therefore, attention was concentrated on the construction of the high-voltage vacuum-tube unit. Construction and test of a vacuum-tube suitable for use with such high constant-potentials—the highest ever attained anywhere—was essentially a research in itself, since it involved voltage-distribution and vacuum-pumping problems of a new order of magnitude. The technique of the vacuum-pumping problem was sufficiently well advanced so that a beam of protons bombarding a target at the base of the tube, operated at about 2 million volts, was demonstrated early in December.

In January 1939 the tube was operated at over 3 million volts, as measured by the range in air of the proton-beam, but seemed limited at this value by oil from the vacuum-pumps which had distilled into the base of the high-voltage tube. The installation of a properly designed baffle-system between the pump and the tube to overcome this trouble was postponed in order to use the equipment for observations on the uranium-fission process. This and other pressing scientific problems have kept the apparatus occupied; therefore, the attempts to improve the tube for operation beyond 3 million volts have not yet been made.

It is clear, however, from the degree of control and the refinement of the observations obtainable, that many years of satisfactory scientific use will be had

with this installation. The adjustments and improvements needed for extending the voltage-range will be made so as to cause minimum interference with the scientific use of the equipment.

In addition to the observations on the fission-process which led to the discovery in this laboratory of the unique delayed-neutron reaction, excitation curves and yields were obtained for a number of reactions which lead to the production of elements useful as radioactive indicators for chemical and biological experiments. Among the most important of these are carbon (20 minutes), nitrogen (10 minutes), sodium (15 hours), phosphorus (2 weeks), and potassium (15 hours), all of which are produced in adequate amounts by the new equipment for use as radioactive "tracers."

NUCLEAR FISSION OF URANIUM AND THORIUM

A new type of atomic transmutation in the heaviest element, uranium, was discovered by chemical methods during January 1939, in Germany. The process is one of fission under neutron bombardment, the uranium-nucleus dividing itself into two roughly similar parts with the release of more than 200,000,000 electron-volts of energy, even though the bombarding neutrons have only $\frac{1}{10}$ electron-volt of energy. This contrast of energies immediately revived the old question as to whether atomic energy could be obtained in amounts of practical importance, since the possibility of a chain-reaction arises if the emission of free neutrons accompanies each fission. Using the new high-voltage equipment, the Department was one of the first laboratories to confirm the discovery of the fission-process by direct observation of the high-energy particles. It was also soon demonstrated that at least part of the fission-processes lead to the emission of free neutrons, because the *delayed* emission of free neutrons (radioactive

half-life, 12 seconds) was promptly discovered at the Department. The real question as to whether the evolution of large amounts of energy can occur is complicated by the fact that both slow neutrons and fast neutrons produce fissions. After conferences with other workers, especially with Professor Fermi and Dr. Szilard of Columbia University, the Department's efforts, because of the special fitness for this purpose of the new high-voltage equipment, were directed toward study of the fissions produced by high-energy neutrons, while the Columbia investigators concentrated attention on the processes involving slow neutrons.

Serious difficulties were encountered in attempting to obtain an unequivocal answer to the question as to whether or not a chain-reaction is possible. There are numerous technical factors which affect the observations, and especially the exact interpretation of any given measurements, so that rather divergent results have been published here and abroad. All the measurements necessarily are made with water near the uranium to slow down the neutrons, and in these measuring experiments practically all the neutrons are captured by the water instead of by the uranium. Thus, no actual evolution of energy has been expected, but only an excess of neutrons. Up to the present, however, no observations are reported or known at any laboratory which indicate that a chain-reaction definitely will occur, even under the best adjustment of conditions. On the other hand, it must also be stated that no data exist which would show that a chain-reaction definitely cannot proceed if such an adjustment is made. Certain interesting questions relating to the rôle of the several species of uranium atoms (isotopes) are being investigated here, but fears of any imminent disturbance of our industrial society by "atomic power" evidently can be disregarded for the present.

NUCLEAR PHYSICS AS A TOOL FOR BIOLOGY AND CHEMISTRY

It is obviously impossible for a specialist in one field of research to have a working knowledge of all the recent developments in other fields of research which may have a useful bearing on his own problems. On the other hand, fundamental work in any scientific field, however specific its own objective may be, has a way of embracing in its significance and its applications many other scientific interests. The Department's work in nuclear physics is an example of this which promises to be of special importance in particular fields of the Institution's activities. Started in 1926 as an attack on the fundamental problems in magnetism, this work in recent years has developed unexpected potentialities as a tool for investigating certain important chemical and biological problems. Radiations from nuclear-physics apparatus have lethal and genetic effects somewhat different from those previously available. This provides new analytical possibilities which are being developed in the Department's laboratory in cooperation with the Institution's Department of Genetics and by Dr. P. S. Henshaw of the National Cancer Institute. Another procedure, of wider usefulness, is that involving the use of radioactive isotopes (species) of the ordinary chemical elements as "tracers" in quantitatively following a given sample of one element through even the most complicated and unknown chemical reactions, in spite of the initial presence of the same element in large amounts. Radioactive isotopes of nearly every chemical element can be produced by the use of nuclear-physics equipment and procedures. During the past two years several programs of cooperative research using radioactive tracers have been put into operation, notably in Copenhagen, in Berkeley, and in Rochester, and have yielded new information on the physical

chemistry and particularly on the biochemistry (physiology) of sodium, phosphorus, iron, and iodine.

A limited attempt to explore the value of this technique was made by the Department's staff in cooperative studies of three problems. With Dr. L. R. Flexner of the Johns Hopkins Medical School, measurements have been made on the rate and amounts of transfer of radioactive sodium across the placental boundary, using pregnant rats, as an initial approach to problems concerning the nutrition and development of the fetus. With Dr. Keith Brewer of the U. S. Department of Agriculture, studies of plant-nutrition are in progress, using radioactive sodium, potassium, and phosphorus. Another project of special interest is the use, in the Department's laboratory, of radioactive carbon by Dr. J. H. C. Smith of the Institution's Division of Plant Biology for studies of the way in which plants take up carbon dioxide in the dark, whether by simple solubility or by the formation of temporary compounds, as a fresh attack on the many broad and unsolved problems of photosynthesis.

Plans are being developed for the construction of special facilities, including a large cyclotron, to extend this type of attack to many biological and chemical problems within the Institution and in the many other research laboratories in and near Washington.

THEORETICAL-PHYSICS CONFERENCE

One of the most analytical types of experimental research during the past decade on the chemical and molecular properties of matter has been through studies at very low temperatures, utilizing liquid hydrogen and liquid helium to approach the region of absolute zero. With disturbances arising from the temperature-agitation of the atoms in solid matter thus minimized, it becomes possible to measure the forces and energies

of interaction between atoms and various other molecular and crystalline properties. Qualitative phenomena not observed at higher temperatures, because they involve very small energies per atom, including a host of new data on special magnetic properties of a large variety of substances, have indicated that the future importance of low-temperature studies may even eclipse their past and present position of distinction. A fifth Washington Conference on Theoretical Physics was held in January 1939, again under the joint auspices of the George Washington University and of the Institution acting through this Department. The subject of low-temperature physics was discussed during three days of informal meetings by about twenty investigators from various institutions of this country and abroad.

Experimental and theoretical work in the field of low temperatures is important to researches of the Institution in two ways, namely, in relation to magnetism as a molecular property and in relation to the "free energy" of various chemical reactions, as determined by specific heat-measurements extended to very low temperatures. This Conference focused the attention of members of the Institution on the uses of data obtained at very low temperatures in relation to their own particular investigations. A more serious study is worth while of the possibility that low-temperature data may be a most effective approach to certain major problems in geochemistry and geophysics.

Comment concerning the successful outcome of last year's Theoretical-Physics Conference is not out of place here. The long-standing riddle as to the source of energy of the stars appears to have reached a satisfactory solution in the carbon-nitrogen chain-reaction for producing helium out of hydrogen (carbon is a catalyst and is not used up). This reaction was suggested by Professor

Bethe, a member of the Fourth Conference, as a possible solution of the problem as it was formulated by that Conference. This reaction serves quantitatively to explain the energy-output of the stars of the main sequence. Furthermore, Professor Gamow has recently demonstrated that the three groups of variable stars are exactly those which would be produced by small admixtures of deuterium, lithium, and boron. Details of course remain to be filled in, but the quantitative agreement of the values predicted from nuclear physics with those observationally deduced by the astronomers leaves little doubt as to the validity of the main features of these explanations of the known properties of the stars in terms of the measured properties of atomic nuclei.

MISCELLANEOUS

As the report-year closed, active tests again were started on the use of a modulated-searchlight beam, with a photoelectric receiver tuned to the modulation-frequency, to explore the upper atmosphere. R. E. Hopkins of the University of Rochester and W. H. Mock of the Massachusetts Institute of Technology joined the staff for the summer of 1939 to continue this project. Tests in the laboratory had previously indicated that if mirrors of adequate reflectivity and a photoelectric cell of the proper sensitivity-curve are used in a locality where there is not too much absorption of light in the low atmosphere (the vicinity of Washington is bad in this regard), it should be possible to obtain information as to density of molecules (Rayleigh scattering) and the presence of water-droplets, clouds, haze, or dust (white-light scattering) up to heights at least as great as 50 or 60 km. With aluminized mirrors it may be possible, after some tests and development of filters and light-sources, to make observations on the ozone-layer in the

region below 25 km. Although observations to very great heights cannot be hoped for near Washington, especially during the humid summer weather, the results of these tests are awaited with interest.

The cause of the permanent magnetic field of the Earth, as distinguished from the much smaller variational field caused by currents in the ionosphere and counter-currents in the crust, continues to occupy our attention. None of the advances in physics during the past forty years seems to have given any solid basis whatever for an understanding of this salient geophysical phenomenon. Discussions during the year indicate more strongly than ever that progress on this and a host of other geophysical problems may be made by devising equipment to extend measurements to much higher pressures than have been explored. A critical examination of such possibilities, especially as regards "cascading" of pressures, is in progress. Pressures of one hundred thousand or even two hundred thousand atmospheres, corresponding to depths of several hundred kilometers below the Earth's surface, are desirable and ultimately necessary to determine even the qualitative behavior of materials under conditions so unfamiliar to us. Any finally detailed knowledge of the behavior of the matter inside the Earth is probably forever beyond reach, since its exact chemical composition at all points will certainly never be known, but observations on the mechanical, thermal, magnetic, and electric properties of typical materials under extreme pressures can be relied on to give much better understanding of the Earth and its structure than we now have.

The members of the staff and guests concerned with the nuclear-physics work during the report-year were Hafstad, Heydenburg, Meyer, Ramsey (Carnegie Institution Fellow from June 1), Roberts

(Carnegie Institution Fellow throughout the year), Schmidt, Tuve, Professor E. O. Salant of New York University (Guest Investigator from February 15), and Dr. P. Wang, Fellow of the China Foundation (Guest Investigator from September 9, 1938 to May 10, 1939).

PUBLICATIONS

Publications relating to the above investigations are noted in the bibliography below.

Several demonstrations were conducted in the Atomic-Physics Observatory for various visiting groups, notably for 129 members of the American Institute of Electrical Engineers. Formal talks were presented as follows: American Physical Society, December 28, 1938, by Heydenburg, Hafstad, and Tuve on "Proton-proton scattering" and by Roberts and Wang on "The transmission of medium fast neutrons"; Physics Club, University of Pittsburgh, May 23, 1939, by Roberts on "Uranium fission"; American Physical Society, June 23, 1939, by Tuve on "Discussion of experimental information regarding fission processes."

COOPERATION IN NUCLEAR PHYSICS AT UNIVERSITY OF WISCONSIN

Professor G. Breit of the University of Wisconsin continued as Research Associate and consultant. The work done by him and his associates is summarized below.

Proton-proton scattering. Most of the time during the past year was spent on the analysis of experiments of Tuve, Heydenburg, and Hafstad, and of Herb, Kerst, Parkinson, and Plain on the scattering of protons by protons. The main results of this study are:

a. The *range of force* between protons in the 1S -state is approximately 25 per cent shorter than has been thought likely from the mass-defects of hydrogen and helium isotopes. Using the Gauss error

potential $Ae^{-\alpha r}$, the best over-all fit is obtained with $A=51.4$, $\alpha=21.6$ (units $mc^2=500$ kev for A , 9×10^{-13} cm for r). The value of α previously believed likely was 16.

Using a constant potential through a distance 2.81×10^{-13} cm, the experimental data are represented satisfactorily. The magnitude of the potential energy which must be assumed within this distance is 10.5 million electron-volts. If the Coulomb repulsion is supposed to act within this distance as well, then the potential energy is 11.3 million electron-volts.

b. At the higher energies (900 to 2400 kev) there is so far consistent evidence only for the presence of a scattering anomaly represented by a spherically symmetric wave in the system of the center of mass of the two protons. Scattering anomalies represented by asymmetric waves in this system failed to show up. In the lower-energy region (600 to 900 kev) there is some indication of asymmetry, which, however, is not quite certain experimentally. From current theories of nuclear exchange forces one expects an asymmetry at the higher energies which is estimated as 2 per cent of total scattering at a scattering angle of 20° . Experiment indicates that the effect is probably less than 1 per cent. There is thus evidence *against* customary exchange-force theories. This evidence is not conclusive because both theory and experiment have some uncertainties. The value of extending observations to higher energies and of improving the accuracy at the energies dealt with so far cannot be overemphasized.

c. In previous comparisons of the proton-proton and proton-neutron force in the 1S -state a tantalizing closeness to equality has been found, but experiments on proton-proton and proton-neutron scattering have always indicated a slight excess of proton-neutron attraction over that between two protons. It has now proved possible to give an interpretation

of the results in which the *two interactions are equal to within the experimental error of the observations.*

An essential factor in this interpretation is the discovery of the meson (heavy electron) in cosmic rays by Anderson and Street. A form of interaction energy between nuclear particles has been derived by Yukawa on the assumption that nuclear particles absorb and emit mesons. This form of interaction is very large at small distances. The proton-proton scattering experiments were fitted by this interaction energy and the best constants were determined by comparison with experiment. The change in the interpretation due to using this potential accounts for the removal of about one-half of the difference between the two interactions.

The remaining part of the difference is removed by an improvement of the value of the scattering cross-section for slow neutrons by protons. The improved measurements were made by Simon in Copenhagen.

d. It has proved possible to test the *shape* of the potential-energy curve representing the interaction between protons by using the observed scattering. Potentials having small extensions going to large distances (like the ordinary exponential) are not favored by experiment.

Disintegration of Li^8 . The analysis of the experiments of Rumbaugh, Roberts, and Hafstad on this disintegration was completed by C. Kittel. He finds that it is possible to fit the experiments using angular momentum 0 or 2 for the ejected alpha particles. The best fit was obtained using angular momentum 2.

K electron capture of Be^7 (in collaboration with J. K. Knipp). The experi-

ments of Rumbaugh, Roberts, and Hafstad on this reaction show that the selection rules of Gamow and Teller are better than those of Fermi. In comparison with beta disintegrations of heavier nuclei, there is an anomalously great probability of the Be^7 reaction. This increase in probability apparently persists down to He^4 . A partial explanation of the very short life of the latter element was given recently by Grönblom.

Scattering of fast neutrons. Formulas for facilitating calculation of theoretically expected scattering were developed in collaboration with C. Kittel.

Expected mean life of hydrogen in its metastable level in interstellar space. Struve and collaborators at Yerkes Observatory have evidence regarding the mean life of the 2s-state of hydrogen atoms in interstellar space. They suppose that transitions to the ground state are due to ions and electrons affecting the metastable atoms. The effects of hyperfine structure of the hydrogen atoms were omitted in their considerations, and calculations were made to take these into account.

Quite recently the effect of simultaneous emissions of two photons was taken into account in collaboration with E. Teller. For the smaller ion-densities this is the main cause of transitions.

Emission of gamma rays by F^{19} under proton bombardment. The work of Herb, Parkinson, and Plain extends the earlier observations of Tuve and Hafstad on the resonance emissions of gamma rays. A number of sharp gamma-ray peaks are found by them. A theoretical discussion was prepared for their paper showing that a likely mechanism is the disintegration into an excited O^{16} nucleus and an alpha particle.

FIELD-WORK AND REDUCTIONS

LAND MAGNETIC SURVEY

Considerable progress was made by Vestine and Wallis in the final revision of field-records for a new volume of the Researches of the Department to include results obtained on land from 1927. Upon request, published and unpublished magnetic data were supplied to interested parties and organizations, for example, the British Admiralty, the Australian Department of Mines, the Department of Lands and Surveys of the Fiji Islands, and observatories. A compilation of all results of magnetic declination in South America was made for the Argentine Aviation Service. Tabulations of geographical positions of magnetic stations were made for several geographical societies.

Instruments now on loan to cooperating institutions, in addition to those at the Cheltenham and Samoa Observatories, include magnetometer-inductor 17 to the Cape Town Magnetic Observatory, magnetometer-inductor 13 to the British East Africa Meteorological Service, magnetometer-inductor 18 to the Aerial, Geological, and Geophysical Survey of Northern Australia, and magnetometer-inductor 6 to the Government Observatory of South Australia.

Determinations of constants and of corrections on international magnetic standards as maintained by the Department with the cooperation of the U. S. Coast and Geodetic Survey at the Cheltenham Magnetic Observatory were made for magnetometer-inductor 16, magnetometer-inductor 17, universal magnetometer 21, magnetometer-inductor 27, dip-circles 222 and 242, earth-inductor 171, la Cour quartz horizontal magnetometers (QHM) 42, 43, and 44, two Askania vertical-intensity variometers, and Berger theodolite-compass 3578.

Determinations of corrections on international magnetic standards were also made at the Watheroo Magnetic Observatory for magnetometer-inductors 18 and 28. Satisfactory experience was gained in the use of the QHM and the Askania vertical field-balance in the magnetic survey in Guatemala.

FIELD-OPERATIONS AND COOPERATIVE SURVEYS

Secular-variation data in Africa were obtained through control-observations at the Cape Town Magnetic Observatory and through observations in Kenya Colony by the British East Africa Meteorological Service.

In Australia control-observations supplied secular-variation information at the Watheroo Magnetic Observatory, and some work was done in Northern Australia in cooperation with the Aerial, Geological, and Geophysical Survey of Northern Australia.

In North America international magnetic standards of the Department were continued in cooperation with the U. S. Coast and Geodetic Survey at the Cheltenham Magnetic Observatory, where CIW sine-galvanometer 1 and CIW Schulze earth-inductor 48 are the standards for horizontal intensity and inclination.

In connection with the Guatemalan Volcanological Expedition of 1939 for the investigation of the volcano Santa María, nine secular-variation stations were reoccupied in Guatemala, namely, Champerico, Cobán, Guatemala City, Huehuetenango, Puerto Barrios, Quezaltenango, Salamá, San Marcos, and Zacapa; distribution-stations were occupied at Chichicastenango, Guatemala City, and Retalhuleu. (See page 63 for particulars regarding observations of magnetic anomalies in the region of the volcano Santa María.)

In South America secular-variation data followed from the control-observations made regularly at the Huancayo Magnetic Observatory.

OBSERVATORY-WORK

The Section of Observatory-Work is in charge of Johnston, with Ledig, McNish, and Scott as assistants. Wait, Torreson, Hendrix, and Miss Balsam completed the compilation of the tabulations of hourly mean values of positive and negative conductivities and of potential-gradient for both observatories over the eleven-year period from 1924 to 1934. These tabulations include electric character-figures and symbols for meteorological conditions and are ready for publication by planograph. Those having direct charge and in residence at the observatories are indicated in the reports on the activities of each observatory.

The extensive geophysical program was maintained at Huancayo (Peru) and Watheroo (Western Australia). At both observatories continuous records were made of the three magnetic elements (declination, horizontal intensity, and vertical intensity), and absolute observations were obtained weekly for the control of the magnetograms. Duplicate magnetographs insured complete records. The observatories obtained electrograms of the atmospheric-electric elements (positive and negative conductivities and potential-gradient) and records of the meteorological elements which will assist in their interpretation. During the year, earth-current records were obtained at both observatories from duplicate electrode-systems; the duplication of the lines again proved helpful in interpretation of records.

Continuous records of conditions in the ionosphere were made at both observatories with automatic multifrequency apparatus constructed by the Department. Arrangements were also made at Watheroo for the continuous record of a fixed-frequency reflection on the multifrequency record. As part of the program of the International Astronomical Union for solar data, daily observations were made with Hale spectrohelioscopes

for three half-hour intervals and for two-half-hour intervals at Watheroo and Huancayo, respectively. The cosmic-ray meter and the three-component seismograph were operated at Huancayo Observatory.

Radio communication was maintained with both observatories; this enabled the Department to prepare and promptly disseminate the weekly American character-figure, C_A . This measure of magnetic activity showed the high correlation-coefficient of +0.94 with the measure of activity ("Kennziffern") adopted for the Niemegk (Germany) magnetograms. Both measures showed a satisfactory correlation-coefficient with the radio-transmission disturbance-figure of the Bell Telephone Laboratories.

Cooperation was maintained in geophysical observations with various observatories and organizations. The Department was assisted in its program by the cooperation of the following organizations: In the United States and possessions, by the Coast and Geodetic Survey at Cheltenham and at Tucson and by the University of Alaska at College; in Africa, by the Trigonometrical Survey of South Africa through its Cape Town Magnetic Observatory and by the British East African Meteorological Service at Nairobi; in Australia, by the Aerial, Geological, and Geophysical Survey of Northern Australia; in the Pacific Ocean, by the Department of Scientific and Industrial Research of New Zealand at Apia, Samoa; and in the Indian Ocean, by the Royal Alfred Observatory in Mauritius.

OPERATIONS AT OBSERVATORIES

The operations at the observatories of the Department and at observatories or organizations with which the Department cooperated are summarized below.

Watheroo Magnetic Observatory, Watheroo, Western Australia. The Watheroo Magnetic

Observatory is situated in latitude $30^{\circ} 19' 1$ south and longitude $115^{\circ} 52' 6$ east of Greenwich, 244 meters (800 feet) above sea-level.

The Eschenhagen magnetograph was in continuous operation, with but a few hours' loss of record occasioned by stoppage of the driving clock. Scale-value determinations of the horizontal-intensity variometer using the magnetic deflection-method were made monthly; vertical-intensity scale-value determinations were made daily by the electrical method. The monthly mean scale-values for both the horizontal and the vertical components of the Earth's field for the calendar year 1938 are shown in table 1.

TABLE 1
SCALE-VALUES OF MAGNETOGRAPHS,
WATHEROO MAGNETIC OBSERVATORY, 1938

MONTH	SCALE-VALUES IN γ /MM			
	ESCHENHAGEN		LA COUR	
	<i>H</i> (reduced to base-line)	<i>Z</i> (means of daily values)	<i>H</i>	<i>Z</i>
January . . .	2.34	3.38	4.19	3.02
February . . .	2.38	3.39	4.55	2.92
March	2.36	3.42	4.39	2.80
April	2.34	3.36	4.61	2.69
May	2.34	3.40	4.76	....
June	2.39	3.54	4.58	2.82
July	2.40	3.53	4.60	2.81
August	2.36	3.52	4.56	2.74
September . . .	2.46	3.49	4.57	2.69
October	2.38	3.52, 3.32	4.60	2.84
November . . .	2.38	3.37	4.57	2.63
December . . .	2.36	3.32	4.62	2.70

The la Cour rapid-running magnetograph was in continuous operation; an overhaul and readjustment of the optical and recording system during the early part of 1939 resulted in improved registration. Scale-value determinations by the electrical method were made monthly as in previous years. The values for both horizontal- and vertical-intensity variometers are given in table 1.

The preliminary mean values of the magnetic elements for all days of 1938, as deduced from the Eschenhagen magnetograms, referring the elements to the north-seeking end of the needle and reckoning east declination and north inclination as positive, are: declination, $-3^{\circ} 26' 3$; horizontal intensity, 0.24682 CGS unit; vertical intensity, -0.51489

CGS unit; and inclination, $-64^{\circ} 23' 3$. The preliminary values of the annual changes in the magnetic elements during 1937.5 to 1938.5 are: declination, $+5' 4$; horizontal intensity, $+5$ gammas; vertical intensity, -41 gammas; and inclination, $-0' 8$.

The recording of earth-potentials for derivation of diurnal variation of earth-currents was made over the system of electrodes as described in previous reports. An examination of the records obtained during the latter half of 1938 gave evidence of some interaction between the long and short lines in both the north-south and the east-west directions. During January 1939 a close examination of both the internal and the external wiring was made and two new electrodes, *Q* and *R*, were installed, 2 miles to the north and 6 miles to the east of the common electrode, respectively. Thereafter, the records were again quite satisfactory. Further improvement in the suspension of the overhead connector lines is in hand.

Air-potentials have been recorded continuously by means of the standard potential-gradient apparatus as in former years. Reduction-factor observations were made quarterly instead of monthly as previously. Positive and negative air-conductivities were continuously recorded and the usual observations for control were made regularly; the only interruptions in the records were those caused by abnormal weather-conditions and the presence of smoke from bush-fires. The preliminary values of the atmospheric-electric elements are shown in table 2 (p. 98).

At the beginning of the report-year the automatic multifrequency ionospheric recorder was in operation over a frequency-sweep of from 16.0 to 3.28 megacycles per second. After the erection of the long antenna on July 19, 1938, the range of frequencies recorded was increased, the limits being 16.0 to 0.516 megacycles per second, and from then on recording was continuous except for short periods, mostly while adjustments and additions to the equipment were being made or when regular operations of maintenance were in progress. During November 1938 a fixed-frequency recording apparatus (operating on 4.8 megacycles per second) was installed, to run during daylight, in conjunction with the multifrequency equipment, for the special study of fade-outs.

During December 1938 the standard controller equipment was installed, this replacing the temporary equipment used previously. During December 1938 a complete recalibration of the transmitter was made, the necessary data for cams to give maximum antenna-current were derived, and these cams were cut and fitted. Systematic manual-control observations and operations of maintenance were made and the scaling and reduction of records were made current. Schedules of communication were maintained between the Observatory and Washington through amateur radio stations W3AMS and W3QP except for two weeks in March 1939, when the transmitter was under repair.

were supplied to approved investigators, at their request, and also to organizations engaged in lines of investigation similar to our own.

Toward the end of 1938 the tabulations and reductions of data for the Observatory had, through various causes, fallen somewhat into arrears; however, by the end of June 1939 these were again current.

The grounds, buildings, and equipment were maintained. The mounting of the long antenna poles for the ionospheric recorder, under the supervision of Mr. Berkner, was completed.

It is gratifying to be able to report on the continued support and cooperation of indi-

TABLE 2
PRELIMINARY MONTHLY MEAN VALUES OF ATMOSPHERIC-ELECTRIC ELEMENTS,
WATHEROO MAGNETIC OBSERVATORY, 1938

MONTH	NUMBER OF SELECTED DAYS	POTENTIAL-GRADIENT		AIR-CONDUCTIVITY, UNIT 10^{-4} esu			
		Reduction- factor	Value in v/m	λ_+	λ_-	$\lambda_+ + \lambda_-$	λ_+ / λ_-
January.....	20	1.10	102.2	1.54	1.49	3.03	1.03
February.....	23	....	115.3	1.37	1.30	2.67	1.05
March.....	22	....	103.6	1.52	1.39	2.91	1.09
April.....	21	1.14	98.6	1.76	1.55	3.31	1.14
May.....	21	....	73.4	2.28	2.00	4.28	1.14
June.....	19	....	76.6	2.25	1.89	4.14	1.19
July.....	14	....	82.7	2.34	1.97	4.31	1.19
August.....	13	....	88.4	2.01	1.78	3.79	1.13
September.....	18	1.19	77.2	2.11	1.86	3.97	1.13
October.....	21	....	85.5	1.80	1.63	3.43	1.10
November.....	21	....	94.0	1.56	1.33	2.89	1.17
December.....	17	1.12	104.0	1.50	1.29	2.79	1.16
Total and means.....	230	1.14	91.8	1.84	1.62	3.46	1.13

Visual observations of solar activity, using the Hale spectroheliograph, were made in accordance with the international scheme under which the Observatory is allotted three half-hour periods each day during which the Sun's disk is continuously scanned. Monthly summarized reports of this work were prepared and transmitted to Washington.

The usual meteorological observations as outlined in previous reports were made daily and all the self-recording meteorological instruments were kept in continuous operation. Monthly summaries were supplied to the Australian Commonwealth Weather Bureau at Melbourne as in former years.

Scientific data, summaries of results, and information as to equipment and technique

were supplied to approved investigators. We are particularly indebted to John S. Lacey of radio station W3AMS (Washington Grove, Maryland) and John B. Morgan of radio station W3QP (Blue Bell, Pennsylvania) for maintenance of radio traffic to and from the Washington office. G. A. Scott, Senior Radio Inspector for Western Australia, and his staff continued keen interest in the ionospheric research and granted special facilities which have materially assisted this work. Professor A. D. Ross of the Department of Physics of the University of Western Australia gave valued assistance in various ways. Material assistance was given by various officials of the Australian Commonwealth Department of Trade and Customs, who have shown

appreciation of the value of the scientific work by favorable action on numerous requests for remission of duty connected with the importation of necessary equipment.

Green continued as Observer-in-Charge until December 31, 1938, when he was succeeded by Parkinson, who returned to the Observatory after a period of field-work. Berkner was attached to the staff between April and December 1938, in charge of the installation of the automatic multifrequency ionospheric recording equipment. Hogan left the Observatory during August 1938, to accept an appointment in Canberra. Prior and Chamberlain continued as junior observers. On December 1, 1938, E. McCarthy joined the staff as junior observer.

With the ever-increasing importance and scope of the work of the Observatory, it is especially pleasing to make grateful acknowledgment of the zeal of the entire staff and to place on record an appreciation of the efficiency of their service.

Huancayo Magnetic Observatory. The Observatory is situated in latitude $12^{\circ} 02' 7''$ south and longitude $75^{\circ} 20' 4''$ west of Greenwich, in the central valley of the Peruvian Cordillera at an elevation of 3350 meters (11,000 feet) above sea-level.

F. T. Davies was Observer-in-Charge with the assistance of H. W. Wells as first assistant, and W. Culmsee and H. E. Stanton as observers, the latter until March 1, 1939, when he returned to the Washington office. T. Astete and A. Macha continued as clerical assistants, and V. Murga was appointed temporary clerical assistant on February 27, 1939.

Two magnetographs, one an Eschenhagen, the other a la Cour rapid-run type, were operated continuously. Control of base-lines was obtained by weekly absolute magnetic observations. Scale-values for H and Z of the la Cour magnetograph were determined electrically once each month. Scale-values for D and H of the Eschenhagen magnetograph were determined electrically once each week, and scale-value for Z was determined electrically three times each week. An additional la Cour H -variometer was operated at low sensitivity with the Eschenhagen magnetograph. Monthly reports of the more important magnetic disturbances were forwarded to the office.

Air-potentials were recorded with standard potential-gradient apparatus and scale-values were determined twice each month. Reduction-factors were obtained by comparison with potentials measured on open, level ground at quarterly intervals. Positive and negative air-conductivities were continuously recorded and scale-values were determined twice each month.

Earth-current potentials were recorded continuously with a Leeds and Northrup apparatus. Two separate systems of north-and-south, east-and-west electrodes were used. Relatively few repairs to the wiring system were found necessary during the year.

Two horizontal-component Wenner-type and one vertical-component Benioff-type seismographs were operated. The Wenner seismograph was operated continuously, but the Benioff apparatus was temporarily discontinued on December 4, 1938, to send the driving mechanism to the maker for repairs. Analyses of the more important seismic disturbances were made regularly and code-messages were sent by radio to the office. Considerable interest attaches to a phenomenal delay in the arrival-time of the P -wave at the Observatory from the violent Chillan (Chile) earthquake of January 25, 1939, for which the P -wave was 26 seconds later in arrival than might have been expected from the known location and time of the shock and the normal velocity of the wave.

A Compton-Bennett cosmic-ray meter recorded cosmic-ray intensities continuously. Further evidence of weakening of cosmic-ray intensity associated with strong magnetic storms was found. Preliminary reports on three of these occurrences during April 1939 were prepared.

The Hale spectrohelioscope was used daily, as conditions of sky permitted, for observation of the Sun. The assigned daily periods of observation for this Observatory were from $15^h 30^m$ to 16^h and from $16^h 30^m$ to 17^h , GMT. Monthly reports of spectrohelioscope observations were prepared.

The multifrequency ionospheric recorder was operated continuously except for short intervals necessary for maintenance and minor modifications or repairs. Scalings and tabulations of critical frequencies and virtual heights of the several ionospheric regions were kept current. Following the practice

initiated last year, quarterly reports were submitted on ionospheric conditions and characteristics. An annual report was prepared, summarizing the results of the first year of continuous recording. The predominance of the annual characteristics of F_2 -region critical frequencies was confirmed. The F_2 -region virtual-height characteristics at Huancayo, however, have been shown to assume the features of both northern and southern hemispheres, with no pronounced local seasonal effect. Special investigations were conducted to determine effects of magnetic disturbances on the ionosphere. It was shown that the most characteristic effect is a sharp decrease in F_2 -region critical frequencies, which is frequently associated with or followed by a sudden increase in virtual height. The effect is noticeable during most, but not all, intense magnetic disturbances. An interesting result from this investigation is that ionospheric and cosmic-ray effects may occur simultaneously during a magnetic storm. The ionospheric effect occurs at a distance of 200 to 400 km from the Earth, while the cosmic-ray effect requires a current-system many hundred km from the Earth. Modifications of the equipment are under way as time permits, to prepare the apparatus for installation of an additional fixed-frequency recorder for special studies of phenomena such as radio fade-outs, sporadic E -region ionization, etc.

Radio communication through John B. Morgan's radio station W3QP (Blue Bell, Pennsylvania) was maintained to forward messages about magnetic disturbances, daily magnetic characterization, and analyses of earthquake records.

A 6-kw Diesel engine-generator was installed during October 1938; it proved very satisfactory. This generator makes possible a saving in cost of operation through the use of fuel oil instead of gasoline. A direct-current voltage-control developed by Stanton and Wells proved a useful addition to powerhouse equipment; it adjusts the output of the Diesel to the existing load-conditions and maintains a fixed floating charge to the banks of storage-batteries. This unit also simplifies alternating-current-frequency control for the ionospheric equipment.

Observations of barometric pressure, maximum and minimum temperatures, relative

humidity, rainfall, cloudiness, and direction and velocity of wind were made daily at 8 A.M., 75° west meridian time. Measurements of the air-content of condensation-nuclei were made daily at the same hour. Continuous records were obtained with barograph, thermograph, hygrograph, anemograph, and sunshine-recorder. Computations and tabulations of magnetic, atmospheric-electric, earth-current, ionospheric, and meteorological studies were kept current; the records and tabulations were forwarded each month to the office, together with seismograms and cosmic-ray records and spectroheliographic data. Comparison of the Richard barograph and Negretti microbarograph records with those of an optical microbarograph designed by Stanton and Culmsee showed that the Richard continuous records were satisfactory for correction of the cosmic-ray meter and ordinary barometric tabulations. The Negretti microbarograph had to be returned to the maker for adjustment to correct for hysteresis effects. The optical microbarograph was found to give very reliable and sensitive records, and this instrument is therefore being kept assembled for test-purposes.

Monthly tabulations of barometric pressure, direction and velocity of wind, and sunshine, together with summaries of the daily meteorological data at 8 A.M., were supplied to the Servicio Meteorológico Nacional del Perú and also to the Centro Geográfico Departamental de Junin, Perú. A report on rainfall-data at this Observatory for the 16-year period 1923 to 1938 was prepared, and copies forwarded to the Washington office and to the Servicio Meteorológico del Perú; this report showed that the average annual rainfall for these 16 years was 28.01 inches.

Preliminary mean values of the magnetic elements for all days of 1938 as deduced from the Eschenhagen magnetograms, referring the elements to the north-seeking end of the needle and reckoning east declination and north inclination as positive, are: declination, $+7^\circ 04.4$; horizontal intensity, 0.29572 CGS unit; vertical intensity, 0.01167 CGS unit; and inclination, $+2^\circ 15.5$. The preliminary values for the annual changes in the magnetic elements during 1937.5 to 1938.5 are: declination, -3.7 ; horizontal

intensity, -22 gammas; vertical intensity, $+2$ gammas; and inclination, $+0^{\circ}2$.

Preliminary monthly mean values of the atmospheric elements are given in table 3. Reduction-factor observations were made quarterly instead of monthly as heretofore. The values of atmospheric-electric elements were derived from 174 selected days during the year. The mean value of potential-gradient in the dry season was 49.5 volts per meter and in the wet season 46.3 volts per meter.

Apia Observatory, Western Samoa. The Department continued cooperation with this Observatory through its Acting Director H. B. Sapsford and staff in the program in terrestrial magnetism and atmospheric electricity. This Observatory also undertakes observations in other fields of geophysics, including meteorology and seismology.

CIW magnetometer 9 and CIW earth-inductor 2 were on loan for absolute observations of declination, horizontal intensity, and inclination. Defects resulting from corrosion,

TABLE 3
PRELIMINARY MONTHLY MEAN VALUES OF ATMOSPHERIC-ELECTRIC ELEMENTS,
HUANCAYO MAGNETIC OBSERVATORY, 1938

MONTH	NUMBER OF SELECTED DAYS	POTENTIAL-GRADIENT		AIR-CONDUCTIVITY, UNIT 10^{-4} ESU			
		Reduction- factor	Value in v/m	λ_+	λ_-	$\lambda_+ + \lambda_-$	λ_+ / λ_-
January.....	11	....	52.2	4.13	4.28	8.41	0.97
February.....	10	....	48.6	4.17	4.12	8.29	1.01
March.....	13	1.20	48.4	4.53	4.40	8.93	1.03
April.....	10	....	46.2	4.21	4.34	8.55	0.97
May.....	21	....	47.2	4.81	5.02	9.83	0.96
June.....	18	1.15	46.9	4.90	5.06	9.96	0.97
July.....	27	....	54.1	4.61	4.68	9.29	0.99
August.....	19	1.16	53.0	3.95	4.36	8.31	0.91
September.....	11	....	45.9	4.84	5.14	9.98	0.94
October.....	10	....	46.2	4.80	5.18	9.98	0.93
November.....	10	....	42.8	5.35	5.62	10.97	0.95
December.....	14	1.16	40.4	5.36	5.40	10.76	0.99
Total and means.....	174	1.17	47.8	4.64	4.80	9.44	0.97

COOPERATION WITH OTHER OBSERVATORIES

Cheltenham Magnetic Observatory, United States. The cooperative program with this Observatory under the direction of the U. S. Coast and Geodetic Survey was continued. CIW sine-galvanometer 1 and CIW earth-inductor 48 were used for absolute standards in horizontal intensity and inclination. With the generous assistance of Observer-in-Charge Ludy and G. Hartnell of the Observatory's staff, the precision cosmic-ray meter furnished automatic records of cosmic-ray intensity, and the CIW perminvar vertical-intensity induction-variometer gave dependable records of magnetic vertical intensity. The necessary controls of the magnetic equipment used in Guatemala were obtained both before and after the Expedition, with the cooperation of the Cheltenham Observatory staff.

caused by the humid conditions in Samoa, developed in the earth-inductor during March and it was returned to Washington for overhaul.

Continuous photographic records were obtained of declination, horizontal intensity, and vertical intensity during the report-year. Declination and horizontal intensity were recorded with Eschenhagen variometers and vertical intensity with a Godhavn balance.

Atmospheric potential-gradient was measured with a Benndorf electrometer. Standardization-observations for reduction-factor showed that the previous factor of 1.00 still applied. Only 42 days of zero-character occurred in the year 1938, with a mean value of 121 volts per meter. The monthly number of zero-days and average potential-gradients are shown in table 4. The annual average hourly values in volts per meter based on

the monthly means are as follows: 96, 90, 90, 84, 84, 91, 139, 210, 233, 174, 126, 115, 112, 103, 98, 97, 95, 98, 125, 171, 155, 128, 105, and 93.

server-in-Charge J. Hershberger and R. F. White. The preliminary scaling of the atmospheric-electric observations was done by Mrs. G. Dewey, in part-time service of the De-

TABLE 4
POTENTIAL-GRADIENT AND METEOROLOGICAL SUMMARY, APIA OBSERVATORY, 1938

MONTH	POTENTIAL-GRADIENT		METEOROLOGICAL ELEMENTS					
	Zero-days (no.)	Value (v/m)	Pressure (inches)	Temp. (°F)	Rainfall (inches)	Rel. hum. 9 A.M. (per cent)	Sunshine (hours)	Wind- velocity (miles/hr.)
January.....	8	128	29.737	80.2	20.64	79	210.7	5.7
February.....	0	...	29.760	79.3	13.35	80	142.0	5.3
March.....	8	123	29.815	79.2	10.80	78	185.9	6.0
April.....	1	118	29.819	79.1	6.57	80	202.5*	4.1
May.....	2	103	29.836	78.5	8.79	79	210.5	6.4
June.....	5	132	29.872	79.0	3.73	79	236.3	7.0
July.....	5	140	29.890	79.8	5.86	76	290.8	9.7
August.....	4	139	29.891	78.7	5.26	79	254.7	9.8
September.....	6	111	29.896	79.0	2.13	72	297.6	8.3
October.....	1	102	29.899	79.0	8.04	73	288.8	6.4
November.....	1	102	29.765	77.9	33.35	84	99.4	5.9
December.....	1	138	29.791	79.6	20.94	80	237.5	7.9
Total or mean.....	42	121	29.831	79.1	139.46	78	2656.7†	6.9

*Record for April 13, 1938 lost.
†364 days only.

TABLE 5
PRELIMINARY MONTHLY MEAN VALUES OF ATMOSPHERIC-ELECTRIC ELEMENTS,
TUCSON MAGNETIC OBSERVATORY, 1938

MONTH	NUMBER OF SELECTED DAYS	POTENTIAL-GRADIENT		AIR-CONDUCTIVITY, UNIT 10^{-4} ESU			
		Reduction- factor	Value in v/m	λ_+	λ_-	$\lambda_+ + \lambda_-$	λ_+ / λ_-
January.....	30	...	57.8	2.29	1.92	4.21	1.19
February.....	24	1.24	51.1	3.07	2.16	5.23	1.42
March.....	20	...	53.3	2.54	2.11	4.65	1.20
April.....	13	...	46.8	2.62	2.36	4.98	1.11
May.....	17	1.28	46.5	2.74	2.50	5.24	1.10
June.....	15	...	52.7	2.76	2.55	5.31	1.08
July.....	16	...	51.8	2.61	2.42	5.03	1.08
August.....	8	...	45.7	2.97	2.67	5.64	1.11
September.....	18	...	44.1	2.47	1.97	4.44	1.25
October.....	11	1.27	44.0	2.61	2.35	4.96	1.11
November.....	19	...	50.0	2.66	2.42	5.08	1.10
December.....	13	...	56.4	2.36	2.05	4.41	1.15
Total and means.....	204	1.26	50.0	2.64	2.29	4.93	1.16

Tucson Magnetic Observatory, United States. The Department's equipment for recording atmospheric potential-gradient, positive and negative air-conductivities, and earth-currents, through the cooperation of the U. S. Coast and Geodetic Survey, was efficiently operated and controlled by Ob-

partment. The preliminary monthly and annual values of the atmospheric-electric elements are given in table 5.

The line-connections to the electrodes were maintained through the courtesy of the Bell Telephone Laboratories. The earth-current records are normally complete for the year.

Earth-current records for this and previous years were extensively used in an investigation of earth-current activity with the sunspot-cycle.

Cape Town Magnetic Observatory, South Africa. Cooperation with this Observatory of the Magnetic Branch of the Trigonometrical Survey of the Union of South Africa was continued through the loan of apparatus. Control of declination, horizontal intensity, and vertical intensity is maintained, using CIW magnetometer 17 with earth-inductor attachment.

The final values of the magnetic elements for all days during 1937 and the preliminary values during 1938 for the Watheroo and Huancayo magnetic observatories are shown in table 6.

REDUCTION OF ATMOSPHERIC-ELECTRIC AND GEOELECTRIC DATA

The tabulations of hourly values for atmospheric-electric records from the Watheroo and Huancayo Magnetic Observatories for the 11-year period 1924-

TABLE 6
ANNUAL VALUES OF THE MAGNETIC ELEMENTS AT THE WATHEROO AND HUANCAYO MAGNETIC OBSERVATORIES AS BASED UPON MAGNETOGRAMS FOR ALL DAYS

YEAR	DECLINATION, <i>D</i>	INCLINATION, <i>I</i>	INTENSITY-COMPONENTS					LOCAL MAGNETIC CONSTANT, <i>G</i>
			Horizontal, <i>H</i> (γ)	Total, <i>F</i> (γ)	North-south, <i>X</i> (γ)	East-west, <i>Y</i> (γ)	Vertical, <i>Z</i> (γ)	
WATEROO MAGNETIC OBSERVATORY								
1937.....	3° 31.7W	64° 22.5S	24677	57060	24630	—1519	—51448	35646
1938.....	3 26.3W	64 23.3S	24682	57099	24638	—1480	—51489	35665
HUANCAYO MAGNETIC OBSERVATORY								
1937.....	7 08.3E	2 15.3N	29594	29617	29364	3678	1165	29599
1938.....	7 04.6E	2 15.5N	29572	29595	29346	3643	1167	29577

Royal Alfred Observatory, Mauritius, Indian Ocean. The loan of CIW marine-inductor 4 and galvanometer to this Observatory was continued for the control of the vertical-intensity records.

College, Alaska. Professor E. H. Bramhall continued work in the laboratory preparing equipment for recording ionospheric conditions.

REDUCTION OF MAGNETIC DATA

The Section of Observatory-Work continued the reduction of the magnetic data from Watheroo and Huancayo observatories. Data from Watheroo for 1936 and 1937 and from Huancayo for 1937 were reduced. Work is now progressing on current magnetic records for 1938 and 1939.

1934 for planographic reproduction in publication were completed by Wait, Torreson, Hendrix, and Miss Balsam. These tabulations of potential-gradient and positive and negative conductivity show in detail, by the use of symbols, meteorological notes for every disturbed day in the whole interval. Preparation of various discussions based on these tabulated results is under way. Preliminary compilations of the atmospheric-electric records obtained at the Tucson Magnetic Observatory were kept current by Mrs. Dewey.

Final reduction and preparation of data for publication of the earth-current data obtained from registrations at Tucson, Watheroo, and Huancayo were kept practically current by Rooney.

REDUCTION OF *CARNEGIE* DATA

Final revision of manuscripts for two volumes of physical and chemical results obtained on the *Carnegie* is under way.

Graham, until his appointment in September 1938 on the faculty of the Texas

Christian University, continued study of the specimens collected by the *Carnegie*. He was assisted through August 1938 by Mrs. M. Doudoroff in the investigation of the distribution of the genus *Ceratium*.

INSTRUMENT-SHOP

Steiner, in charge of the instrument-shop with the assistance of Lorz, Haase, Huff, A. Smith, Fogel, Malvin, and Quade, was responsible for the construction of new equipment and experimental apparatus, for repairs and improvements on instruments, apparatus, buildings, and grounds, for the preparation of exhibits, and for special and miscellaneous work relating to instrumental matters.

Good progress was made on the pri-

mary magnetic standard, including the construction of appliances required for precise determination of dimensions of the coil. Equipment for the thyatron frequency-controller at the Watheroo Magnetic Observatory was constructed. Schulze earth-inductor 2 and galvanometer 28A of the Apia Observatory and CIW magnetometer-inductor 26 were completely overhauled. A third ionospheric equipment was begun.

MISCELLANEOUS ACTIVITIES

Active part was taken in meetings of American scientific societies through communications and colloquia. Nine papers were presented at the annual meeting of the American Geophysical Union. Various members of the staff took part in meetings and colloquia of the Patent Office Society, Philosophical Society of Washington, Division of Terrestrial Magnetism and Seismology of the United States Coast and Geodetic Survey, Catholic University of America, American Physical Society, University of Pittsburgh, and Cosmic-Ray Symposium at the University of Chicago. Bartels gave weekly lectures at the University of Berlin on "Physics of the highest layers of the atmosphere," "Harmonic analysis in geophysics," and "Seismology"; at the meeting of the German Geophysical Society in October he conducted a symposium on geomagnetic records with respect to phenomena in the ionosphere and effects of cosmic rays

and gave a talk on "Tidal effects in atmospheric pressure and geomagnetism."

Chapman and Bartels completed the manuscript of a textbook entitled *Geomagnetism*, which is now being printed by the Oxford University Press, Oxford, England. In the preparation of this they made extensive use of the Department's work. The reading and correction of final proofs of volume 8 of the National Research Council's series "Physics of the Earth," entitled *Terrestrial magnetism and electricity*, was practically completed. (This volume of 794 pages, published by the McGraw-Hill Book Company, Inc., for the National Research Council will be issued in August 1939.)

Exhibits. The Department's contributions to the annual exhibit of the Institution in December were concerned with (1) fossil magnetism and (2) structural forces within the atom. The first included apparatus for testing the magnetism of rocks, core-samples taken from

the ocean's bottom (in cooperation with the Geophysical Laboratory), and specimens of varved clays. A prominent feature of the second exhibit was an exact model and section (scale 1 inch to the foot) of the Atomic-Physics Observatory; in this actual working model, voltages up to 200,000 volts were obtained. The model was later exhibited by request at the December meeting of the American Association for the Advancement of Science, in Richmond, Virginia, and is now at the New York Museum of Science and Industry.

Institution activities. Active part was taken by various members of the staff in special committees of the Institution on physical sciences, coordination of cosmic-ray investigations, buildings, lectures, exhibit, and Central American volcanological investigations.

Library. There were 597 accessions to the library during the report-year; the total number of accessioned pamphlets and books is now 25,352. The author and classification card-indexes were maintained not only for the accessioned books and pamphlets, but also for all important articles of interest in current scientific journals, of which about 100 are regularly on file in the library.

Librarian Harradon continued as an Associate Editor of the *Journal of Ter-*

restrial Magnetism and Atmospheric Electricity. He made translations of letters and documents as necessary and took a large part in the preparations for the Seventh Triennial Assembly of the International Union of Geodesy and Geophysics, held in Washington during September 1939.

The number of scientific publications by members of the staff through 1938 is 1810. Reprints of published articles were mailed from time to time to interested institutions and individuals. This distribution was in charge of Dove. A large number of reports and manuscripts were typed by Dove, who also acted as secretary to the Director and continued in charge of the general correspondence files.

Office administration. Accounts, audits, numerous reports, and correspondence required in the administration of the office were looked after by M. B. Smith, administrative assistant, with the aid of Moats, Singer, and Dove. Capello, secretary and property-clerk, had charge of shipments and inventory and prepared many manuscripts. Numerous illustrations, drawings, charts, and sketches for articles, lantern-slides, and exhibits were prepared by Hendrix. The photographic work required was done by Ledig.

DIVISION OF PLANT BIOLOGY¹

H. A. SPOEHR, CHAIRMAN

One of the most significant contributions of biochemistry to a clearer understanding of life processes has been the development of concepts of how the intricate series of chemical reactions of the living cells are brought about through the agency of enzymes. It is one of the most remarkable properties of the normal life of the cell that these enzymatic reactions occur in a stepwise manner, in an apparently orderly sequence, and at an intensity and rate adapted to the conditions essential for cellular life. In the catabolic processes in which molecules of relatively high energy content are broken down, the reactions are regulated through an integrating system of enzymes resulting in a gradual release of energy for vital functions. The plant cell in particular is also characterized by a high capacity for synthetic reactions through which the great multiplicity of substances found in plants are formed from the relatively simple compounds by means of enzymatic reactions. It would appear that these orderly and integrated systems of enzymatic reactions constitute at least one of the chief characteristics of cellular life.

To a very large extent what has been learned regarding the composition of living things and of their enzymes has been based upon information gained from the chemical analysis of organisms. Preparations of enzymes and other cellular constituents must of necessity be obtained from organisms that have been killed. From freshly killed organisms there have thus been obtained preparations which exhibit some of the reactions

which occur in the living organisms. Yet it must be realized that in a large measure the very essence of the problem has still eluded the efforts of the biochemist. Among the striking properties of living organisms are the extreme sensitiveness and the delicacy of the fine adjustments which characterize the enzymatic reactions. Living cells contain many substances which are so labile that they are rapidly destroyed immediately after the death of the cells. Thus, it has been found that some of the components of the cell's photosynthetic apparatus had until recently escaped detection, because of their extreme sensitivity, particularly when in contact with the killed tissue of the plant. Similarly, many of the enzymatic reactions are drastically altered after the death of the cells, and this applies particularly to some of the synthetic processes. For example, even very slight injury to the photosynthetic apparatus results in complete cessation of the photosynthetic process. And even some of the steps following the photosynthetic reaction per se, such as the synthesis of starch, are completely arrested with the death of the cell. It is, consequently, highly probable that many of the chemical systems which have been postulated as existing in living organisms, as also the enzyme preparations which have been isolated from them, represent but fragments of the systems and enzymatic complexes as they exist in the living cells, the more labile and sensitive constituents having been destroyed or inactivated on the death of the cells. The most obvious cause for this destruction of important constituents of the living cells appears to be oxidative disintegration.

¹The Central Laboratory of the Division is located at Stanford University, California.

Efforts have therefore been made to determine some of the conditions necessary for the isolation of these highly reactive constituents of plant cells by making a comparative study of the chemical reactions of certain of the components in living and in killed leaves. In this connection a study has been made of the effects produced by death on the chlorophyll and on the carotenoid pigments; of certain fluorescent compounds found in living leaves; of a material which precipitates starch from its aqueous solution, and of ascorbic acid or vitamin C, which is an important constituent of the chloroplasts of leaves. It has been found that the destruction can be prevented by killing the leaves in the absence of oxygen or, in some cases, by killing under conditions which inactivate the enzymes responsible for the rapid oxidation of some of these very labile substances. Certain of these labile cell constituents can also be protected against oxidative destruction through the use of suitable antioxidants, such as hydroquinone. Refinements of this general nature in the methods used for the extraction of important cell constituents are yielding results of much value for the elucidation of the intricate physical chemical systems involved in photosynthesis. Progress is, of course, primarily dependent upon the development of special techniques, which as they are developed also find application in other phases of biochemistry.

In continuation of the investigations of the mechanism involved in the absorption of carbon dioxide by the green leaf, which is the first step in the process of photosynthesis, experiments have been inaugurated for the use of radioactive carbon dioxide. Because of the fact that this carbon dioxide can, by virtue of its radioactive properties, be differentiated from ordinary carbon dioxide, it is expected that the course of the chemical reactions involved in its reduction and

elaboration into carbohydrates can be followed in more detail. This investigation has been made possible through the invaluable cooperation of the staff of the Department of Terrestrial Magnetism and through the opportunity of using the facilities of this laboratory of the Carnegie Institution.

Besides these efforts to gain a better understanding of the photosynthetic apparatus, that is, of the physical chemical system responsible for photosynthesis, the problem is being approached from quite another side. The efficiency with which the green plant stores radiant energy may be expected to contribute valuable information concerning the chemical steps by which the process is carried out. Photosynthetic efficiency is measured by observing the minimum number of light quanta which must be absorbed by the plant to enable it to produce a unit amount of carbohydrate. Since each absorbed quantum can provide energy for only a single photo process, the minimum number of quanta required should indicate the number of photo processes by which the plant accomplishes carbohydrate synthesis. Theoretical considerations have made it seem improbable that less than 4 quanta could suffice to provide the energy necessary per unit of carbohydrate produced.

The efficiency has now been found to depend on certain factors which have been largely neglected in previous work. By exact control of the conditions under which the plants are grown, and with particular attention to minute quantities of certain mineral nutrients, it has proved possible to carry on photosynthesis with absorption of only 3 quanta per unit of carbohydrate produced. Analysis of the factors contributing to the attainment of such high efficiencies indicates that some of the assumptions upon which the method of efficiency measurement rests are incorrect, and should be subjected to further investigation. While modification

of these assumptions may result in corresponding modification in the quantum values thus far obtained, it will almost certainly lead to fundamental developments in our concept of the chemical steps in photosynthesis.

Investigation of vegetation and the various conditions which control its character and secular changes can be carried on only in areas which are in a natural condition. The desert regions of North America have suffered less disturbance than the more favored ones. In them it is possible to find communities of plants which have resulted from a long interplay of biological and physical processes and in which precise conditions of adjustment have been reached. The simplicity of the plant life of the desert, with its relatively small number of individuals and species, serves to clarify the study of the relation of the environment to the plant. The severity of the desert environment has made survival dependent upon distinctive types of structure, physiological response, and ecological behavior.

The fruitful results of field investigations in the Sonoran Desert under the direction of Dr. Forrest Shreve have led to extension of work into the poorly known plateau desert of Texas and northern Mexico. The aims of further exploration are to place on record a comprehensive description of the vegetation and to determine the major climatic and soil influences involved in its diversity. A full knowledge of the flora and a sound taxonomic revision of it constitute an important aid in themselves and an essential basis for ecological work.

In the field work carried on in the deserts of the southwestern United States and northern Mexico, considerable attention has been given to the natural communities of plants, their definition, composition, and distribution. As this work has been extended over a larger

area it has been found that individual species have different associates in the various parts of their ranges. This suggests that the life requirements of associated species are not identical, and that the amplitude of the conditions favorable for one plant may be much greater than for another. It seems clear that an understanding of natural plant communities can best be had by investigation of their dominant individual members. It has long been evident that the adjustment of plants to arid conditions has been made in a great variety of ways. The program of desert investigation is concerned with the study of some of these adjustments and of the physical conditions under which they have been made.

The past year has seen the conclusion of all the field projects in the more distant parts of the Sonoran Desert. The rainfall observations carried on for a number of years have been concluded. A fresh examination has been made of the northern borders of the Sonoran Desert in Arizona in order to determine the rôle of grassland and arid chaparral as types of vegetation bounding the desert on the north. Mr. Howard S. Gentry, a visiting investigator, spent five months in southern Baja California and explored the southernmost desert part of the peninsula as well as the mountains of the Cape region. The results of the ecological and taxonomic investigations carried out in the Sonoran Desert during the past years are being prepared for publication.

Reporting on his ecological investigations, Dr. F. E. Clements points out that among the results of the past year are three of special interest, which illustrate the three primary lines of inquiry in dynamic ecology. In the search for active evolution in nature, the outstanding example during several decades was discovered on the seaward slopes of the Santa Monica Mountains in southern

California. An increase in the amount of sand available on the beach, due to accelerated erosion resulting from cultivation, has enabled the wind to extend the dune habitat well up the mountain-side. This has profoundly changed the physical factors of water content, soil nutrients, surface temperature, and wind velocity, with corresponding modifications of some twenty-five species, mostly shrub dominants of the coastal sagebrush. Dr. Clements considers that several of these amount to the conversion of one species into a related one, such as *Encelia californica* into *E. farinosa*, local conditions thus repeating the change originally brought about by the climatic shift in the Colorado and Mohave Deserts. A large number of the new dune forms possess the morphological criteria of valid species (*linneons*), but ecologically they are best regarded as a graded series of ecads called forth by a gradient of factors. The modified habitat, community, and dominants are surrounded on three sides by the unchanged sagebrush, thus constituting a natural experiment with adequate controls.

Dr. Clements is of the opinion that similar in general effect but produced by a major climatic shift continental in extent is the differentiation of the grassland climax as a result of the origin of new species of *Stipa*. This took place several millions of years ago, but the confirmation sought by conversion under control has been completed in the experimental gardens of the past two years. The circumpolar *Stipa capillata-comata* has been shown to be a single parental species with parallel derivatives in Eurasia and in North America. In the latter the ancestral *comata* characterizes the original widespread mixed prairie of the Great Plains; the higher rainfall of the Missouri Valley has converted this to *spartea* and the mixed prairie to true prairie. The features of *spartea* are typical of its climate, and the same change is

produced experimentally by limiting the climatic factors in the garden. In like fashion, *comata* may be transformed to *leucotricha*, which in nature appeared simultaneously with the coastal prairie of Texas, or to *pulchra*, which typifies the bunch grass of California. *Pulchra* may be reduced experimentally to form *lepida*, which in nature marks a division of this prairie. Still other climates from Mexico to Argentina have given rise to further species from this stock and to a corresponding community.

Final proof of the nature of the evolutionary changes in the sagebrush cover of the Great Basin, Dr. Clements believes, has been secured during the year, as a result of the cooperation with federal agencies, especially the Soil Conservation Service. From its peculiar appearance and its vast extent, sagebrush had been considered a permanent type of vegetation in harmony with the climate. Two decades ago continued field comparisons led to the view that it was a disturbance community caused primarily by overgrazing, and this was confirmed by preliminary experiments in protection and in burning. In rehabilitating grassland, demonstrations of the effect of burning have been made over wide stretches and various regions, in all of which a climax grass cover reappears in two to three years' time. The original entrance of the sagebrush into the grassland was caused by a shift to warmer and drier, followed by its partial retreat in the opposite phase. The more deeply rooted sagebrush could make no headway against the climax grasses until the latter were weakened by overgrazing, when it took almost complete possession in a single generation. At the same time these to-and-fro migrations carried the sagebrush into neighboring climates, where it became *californica* in the coastal sagebrush and *filifolia* in the sand hills of the Great Plains. More recently, and probably during the period in which it has replaced

the climax grassland, the common sagebrush, *Artemisia tridentata*, has produced a group of dwarf species in response to edaphic, that is, local rather than climatic factors.

The investigations in experimental taxonomy are demonstrating that closely related plants occupying climatically different regions are heritably distinct. The changes that take place in plants when they are moved to a different environment are but temporary and reversible modifications. They do not affect the heritable structure of the plant. Additional evidence has been secured that differences between related plants of unlike regions are linked with their minute heritable structure. This has been directly shown by a study of their chromosomes, the microscopic carriers of the heredity-determining genes. In many cases it was found that a plant group has a constant number of chromosomes in one geographic region, while a closely related group in an adjoining region has another multiple of this number. As many as three multiples were found in closely related forms growing in different climatic regions on the Pacific slope.

This is taken to show that a heritable change in chromosome number has taken place sometime during the evolution of the plant group. The fact that related plants differing in chromosome number also occupy different zones indicates that a new chromosome number may enable a form to occupy a new zone.

It is known from experiments that extremely rare duplications in chromosome number may take place through the application of excessive heat or cold, and equally rare additions of chromosome numbers may occur after interspecific hybridization. Chromosome differences, therefore, are often indicative of the evolutionary history of the group. They also produce a barrier preventing free interbreeding. Forms separated by such barriers belong to different species.

For these reasons the results of the chromosome investigations have changed the outlook on the taxonomic and the evolutionary background of most of the plant groups used in the transplant experiments. These results have also indicated that duplication and addition of chromosome sets have been a very frequent evolutionary means in the adaptation of plant groups enabling them to fit different climatic zones in western North America.

These points, together with many others, are set forth with detailed examples in a volume by Drs. Clausen, Keck, and Hiesey, now in press, on the effects of varied environments on western North American plants. This report covers the taxonomy, distribution, transplant results, and cytogenetics of several of the most complex groups of Western perennials.

The major objectives in Dr. R. W. Chaney's study of Tertiary vegetation in western America have been, first, the description and dating of fossil floras, and, second, their interpretation in terms of earth history. With the sequence and distribution of representative floras established, it has been possible to reconstruct wide migrations during this comparatively late period of geologic time. Predominantly southward in direction, these migrations have brought the redwood forest from Alaska to its present range in California, and have shifted other vegetational units into Mexico and Central America. Changes in climate appear to be responsible for the gradual restriction of many trees toward the south; and it may be added that there is supporting evidence from the record of fossil animals for progressively lowering temperature and rainfall during the Tertiary period.

A similar trend toward cool, dry climate has been observed in the Tertiary floras of Asia. This suggests that, whatever the cause of climatic change, it has

resulted from factors which were regionally widespread. Gradually changing topography, which directly affects circulation of air and water, is commonly considered to be one of the major factors of climatic control. The record of plant

migration on both sides of the Pacific suggests that wider causal factors may also be involved, such as fluctuations in solar radiation, or varying position and distance between the sun and earth, during later geologic time.

BIOCHEMICAL INVESTIGATIONS

H. A. SPOEHR, J. H. C. SMITH, H. H. STRAIN, AND H. W. MILNER

THE ORGANIC NUTRITION OF PLANTS

One of the most difficult problems in the study of the process of photosynthesis is concerned with the final products which are formed. There is as yet no definite knowledge as to the exact nature of these substances, aside from the fact that the general formula of the reaction corresponds closely to the formation of a carbohydrate. It is, however, important to bear in mind that this is a generalized formula. Thus, for example, if besides carbohydrates there were also formed various substances of both a higher and a lower state of oxidation, the generalized formula might still express the over-all reaction. This fact of the possibility of other compounds being formed in the photosynthetic process is of significance in almost every phase of the study of the process. In those methods in which quantitative measurements of the gaseous exchange are employed for determining the rate of photosynthesis, the values represent differences in the rates of photosynthesis and of respiration. Consequently, even relatively small differences in either the respiratory quotient or the photosynthetic quotient would be reflected in differences of both the apparent and the true values of the rates of photosynthesis. The respiratory quotient is, of course, directly dependent upon the nature of the organic material which is consumed, as is the photosynthetic quotient also dependent upon the nature of the material which is synthesized. The assumption that in both cases this mate-

rial is of the general composition of carbohydrate is probably the most important one which has been made and must therefore be subjected to careful scrutiny.

If, as has been commonly assumed, carbohydrate or, more precisely, glucose is the sole product resulting from the photosynthetic reaction, the vast array of organic compounds found in plants must ultimately be synthesized from this substance through an intricate series of chemical reactions. Furthermore, if such is the case, it is conceivable that the plant could synthesize all the organic materials which are essential for its normal growth and development, even in the dark, provided it had available an adequate supply of the primary photosynthetic product, presumably glucose. Many years of painstaking research have demonstrated that it is an almost hopeless task to attain definite and unequivocal results regarding the primary product of photosynthesis by means of chemical analytical methods. Investigations have, therefore, been inaugurated to obtain information on this problem through the general method of determining what organic chemical compounds are essential for the normal development of the plant when these are supplied to the plant through artificial feeding, that is, in the absence of the photosynthetic reaction. This is being done by employing albino plants and normal plants kept in the dark.

This approach to the general problem of the organic nutrition of plants requires more definite information on the nature

of the materials which are consumed in respiration, on the conditions under which the carbohydrates are converted into the materials found in the structural elements of the plant, and on the transformations which the carbohydrates undergo in passing into and from the transitory storage materials such as starch. It was largely with these objectives in mind that the investigations on starch dissolution in leaves, previously reported in the Year Book, were undertaken.

The amylolytic activity of leaves, resulting in the dissolution of the starch of the chloroplasts, is influenced to a remarkable degree by the water content of the leaves. Under conditions of water deficit the starch is hydrolyzed with great rapidity, with the formation of sucrose. It has been generally assumed that this accelerated hydrolytic activity under conditions of water deficit is due to a higher resistance to inactivation on the part of the hydrolytic enzyme as compared with the synthesizing enzyme system. That is, under conditions of water deficit, the starch-synthesizing enzymes are supposed to be more rapidly inactivated than the hydrolytic enzymes, this resulting in the preponderance of the hydrolytic action. It has been found, however, that with change of conditions as to water content of the leaves, the activity of the enzyme complex is directly reversible. That is, leaves which exhibit a high rate of starch dissolution under conditions of water deficit, when permitted to take up water, actually show an increase in their starch content. Both of these reactions occur in the dark, hence independently of photosynthesis. It should be emphasized that this synthesis of starch in leaves kept in the dark has been observed only in species which have a low amylolytic activity, such as tobacco and nasturtium. In leaves with a high amylolytic activity, such as those of the sunflower, in which

the rate of starch dissolution in the dark is relatively high, this can at best only be inhibited by an increase in water content. The amount of starch increase under conditions of greater water content depends upon a number of factors. Of these the age of the leaves and the initial starch content are very significant. Mature tobacco leaves with an initial starch content of about 15 per cent showed an increase of 13 per cent in their starch content, while leaves from the same plant at later dates, when the initial starch content had increased to 25 to 40 per cent, showed increases of about 5 per cent. In order, therefore, to obtain evidence on this phenomenon to a degree which is unmistakably beyond any possible experimental error, it is necessary that the leaves be selected at the proper stage in their development and that the periods of dehydration and rehydration be of suitable length for the leaves used. The phenomenon is nevertheless of considerable importance for the carbohydrate economy of most leaves and for that reason must in all probability be taken into consideration in measurements of both the respiratory and the photosynthetic activity of leaves.

OXIDATION-REDUCTION REACTIONS IN KILLED LEAVES

Interpretation of the process of photosynthesis depends, to a large extent, upon isolation of the labile chemical systems that occur in green leaves. For the extraction of most substances from leaf material, the leaf cells must be thoroughly disrupted, as by grinding. This is accompanied by alteration of many constituents that are believed to form a part of the photosynthetic apparatus. Some of the conditions requisite for extraction and isolation of these reactive compounds have now been determined through a comparative study of the chemical reactions that take place in living and in killed leaves.

When leaves are killed under conditions that are not destructive to enzymes and proteins, many of their constituents are destroyed through reaction with oxygen of the air. Among the substances which have been found to be altered in this way are the yellow and green leaf pigments, certain fat-soluble, fluorescent compounds, a material that precipitates starch from its aqueous solution, and ascorbic acid or vitamin C. This last compound is especially significant because of its strong reducing properties. Substances such as dihydroxymaleic acid and cystine are also oxidized when added to freshly killed leaves. Oxidation of all these compounds can be prevented by killing the leaves in the absence of oxygen or under conditions which are destructive to enzymes, as, for example, in the presence of strong acids.

Oxidation of the yellow leaf pigments, of the fluorescent substances, and of the material which precipitates starch can be prevented by addition of antioxidants. Of a large number of the latter substances tested, hydroquinone proved to be very effective in preventing the oxidation of the yellow pigments. Most of these antioxidants were not oxidized rapidly by anesthetized leaves. Thio-barbituric acid was slowly converted into a new red compound that was strongly adsorbed on cellulose and that exhibited selective absorption of light having a wave length of 531 m μ .

Addition of antioxidants to killed leaves does not inhibit the oxidation of ascorbic acid. This suggests that the oxidation of vitamin C is dependent upon the action of an enzyme and that the oxidation of the yellow pigments is coupled with this or with a similar oxidation of other substances. In this connection, it is significant that rapid oxidation of the yellow pigments does not occur in those plant organs in which oxidation of ascorbic acid is also slow,

as, for example, in oranges and flower petals.

The power of killed leaves to oxidize ascorbic acid varies enormously from species to species. It also varies with the conditions under which the plants are grown. Thus, in killed etiolated barley seedlings ascorbic acid is oxidized more rapidly than in similar plants grown in light. Leaves that are unable to oxidize ascorbic acid rapidly do not inhibit the oxidation of this acid when ground with leaves that possess the oxidation systems. These facts support the view that inability of some leaves to oxidize the vitamin is associated with absence of the oxidation enzymes rather than with the presence of inhibitors of these catalysts.

Leaves of begonia, having a high acidity, when ground with sand are unable to oxidize ascorbic acid. If, however, the whole leaves are killed with anesthetics, such as benzene, rapid oxidation of the reducing substances takes place. This indicates that the ascorbic acid and the enzymes causing its oxidation are structurally isolated from the acids responsible for the high acidity of the leaves. After whole leaves have been killed with anesthetics, most of the ascorbic acid can be expressed with the sap. The material which catalyzes the oxidation of this acid remains in the leaf, a further indication of the complex nature of the oxidation system.

Some of the strongly reducing systems that are found in living leaves appear to persist after their death. Thus, killed whole leaves that have lost their vitamin C through oxidation are able to synthesize this compound when placed in vacuum, and to oxidize it again upon re-exposure to air. Under these conditions, ascorbic acid serves as a catalyst for the transport of hydrogen in plant material. This suggests that ascorbic acid may play a similar rôle in plant metabolism. Reduction of partially oxidized ascorbic acid was not effected by a

mixture of glyceraldehyde and aromatic amines, a synthetic system having pronounced reducing properties. In the presence of air, this synthetic system accelerated the oxidation of pure ascorbic acid.

Dihydroxymaleic acid, another very labile substance exhibiting unusual reducing properties, has been proposed as a constituent of the respiration system of plants. Comparison of the rate of decomposition of this acid with the rate of decomposition of the strongly reducing substances in leaf extracts now indicates that not more than 5 to 20 per cent of the reducing substances found in leaves can be dihydroxymaleic acid. Whether or not this small quantity of reducing material (0.1 to 0.4 gram per kilogram of fresh leaves) is actually dihydroxymaleic acid cannot be determined until more sensitive and specific methods for its estimation are developed.

Although the yellow carotenoid pigments are potentially capable of adding and of liberating large quantities of hydrogen, they have not been found to react with the reducing constituents of leaves or with hydrogen sulphide. In living leaves there is no simple relation between yellow pigments and ascorbic acid. For example, in etiolated barley leaves the quantity of ascorbic acid is relatively small; in green barley leaves it more than twice as great; and in green leaves kept in the dark until they have become yellow, it is again small. The quantities of ascorbic acid and of yellow pigments are greater in green leaves that have been kept in the dark than in seedlings grown in the dark. Yet, when subjected to light, leaves which have lost their chlorophyll by being kept in the dark re-form chlorophyll more slowly than do seedlings which have been raised in the dark. The quantity of ascorbic acid in the yellow portions of variegated ivy and geranium leaves is smaller than that in the green portions of these leaves. It appears that ascorbic acid production is associated with, but is

not directly dependent upon, the process of photosynthesis.

Preservation of the photosynthetic apparatus of killed leaves can be accomplished only by use of antioxidants and anaerobic conditions. Such conditions in themselves prevent the formation of pigments and the process of photosynthesis in living leaves. Formation of chlorophyll in etiolated barley seedlings exposed to light is inhibited when the air pressure is reduced to 0.3 atmosphere or less. Impregnation of the seedlings with hydroquinone also inhibits the formation of chlorophyll in the light and air. This inhibition is not due to permanent injury, because upon removal of the hydroquinone by dialysis, formation of chlorophyll takes place very rapidly. Exposure of etiolated barley seedlings alternately to periods in vacuo and periods in air in continuous darkness results in loss of the carotenoid pigments in portions of the leaf, a change that is irreversible in light. These observations may account in part for some of the difficulties encountered in attempts to produce photosynthesis in killed plant material.

In the course of the investigations of ascorbic acid, relatively large quantities of a substance that precipitates starch from its aqueous solutions were found in leaves of many plants such as grape, sedum, and mesembryanthemum. This substance is extractable from ground leaves, but it is not expressed with the sap from whole anesthetized leaves. The precipitate that is formed with starch is insoluble in cold water and slightly soluble in warm water. It is stained blue by iodine and by iron salts. It is probably related to tannins, which are known to form insoluble compounds with starch and other carbohydrates and to affect the activity of amylase.

ELECTROPHORETIC-CHROMATOGRAPHIC ADSORPTION METHOD

The chromatographic adsorption method for resolving mixtures of pigments has

been modified by application of electrical potential to the ends of the adsorption column. This method has promise of providing a new means for the examination of leaf pigments in aqueous extracts. The method has been successfully used for the separation of a number of closely related dyes, though it has been impossible, as yet, to separate the yellow and green pigments in leaf extracts from one another. With etiolated barley seedlings in which the yellow pigments are not contaminated with chlorophyll, it has been impossible to obtain aqueous extracts sufficiently clear for precise spectral absorption measurements. Here, as is also known for the chlorophylls in aqueous extracts of green leaves, the yellow pigments appear to be associated with the proteins.

ABSORPTION OF CARBON DIOXIDE BY UNILLUMINATED LEAVES

In previous reports on the absorption of carbon dioxide by unilluminated leaves, it has been stated that the absorption takes place both in the sap and in the solid portions of the leaf. During the past year a more complete analysis of the absorption by leaf sap has been accomplished. Such an analysis was necessary in order to explain the anomalous behavior of the leaves of certain species of plants and also to clarify some of the first chemical reactions between carbon dioxide and the leaf constituents.

The leaves of most species of plants so far examined have been found to absorb more carbon dioxide than can be accounted for by the physical solubility of carbon dioxide in the water they contain, on the assumption that the solubility is equal to that in pure water. The behavior of the acid plant, *Sedum praealtum*, presented an exception to this general behavior. It appeared, therefore, that all plants do not possess a chemical mechanism for the absorption and stor-

age of carbon dioxide and that this type of absorption may not be necessary to the photosynthetic process.

If, however, the physical solubility of carbon dioxide in the sap of leaves from this plant is less than in pure water, these leaves might also be found to absorb carbon dioxide in excess of its physical solubility. Measurements of the physical solubility of carbon dioxide in the sap of these leaves substantiated this conjecture, and the leaves of *Sedum praealtum* have been found to behave in the same way as other leaves in respect to the absorption of carbon dioxide.

It may be assumed that the carbon dioxide absorbed in excess of its physical solubility has reacted chemically with some constituent of the leaves. These chemical reactions are of importance to the photosynthetic process. Two types of reaction seem most probable: direct addition of carbon dioxide to certain constituents contained in the sap; and neutralization of the basic sap constituents by carbonic acid to form bicarbonate ion. Quantitative estimation of the bicarbonate ion has indicated that all the absorption takes place by neutralization. This eliminates the absorption by direct addition as an alternative reaction. The quantitative estimation of bicarbonate ion has been made possible by determining the ionization of carbonic acid in solutions of salts, the salt content of which approximated that of leaf sap.

A further deduction may be made from this observation, namely, that carbon dioxide is absorbed by the buffer substances contained in the sap. The complete buffer system has not yet been determined, but a considerable portion of the absorption can be attributed to the phosphates. The quantity of phosphate ion is too small, however, to account for the whole absorption. It is yet to be determined what other buffer substances are partially responsible for the absorption.

From the observations made during the past few years on the absorption of carbon dioxide by unilluminated leaves it has become clear that a carbon dioxide reservoir exists in leaves. Whether this reservoir is a part of the photosynthetic system in leaves is as yet unknown. Recently a number of experiments have been carried out which indicate that part of the carbon dioxide stored in the leaf is depleted by illumination. Whether this carbon dioxide is transformed into organic material remains to be determined. To show that such is the case would establish the integral relation of the carbon dioxide reservoir to the photosynthetic process.

Experiments with radioactive carbon dioxide are in progress which, it is hoped, will yield evidence regarding the participation of the reservoir in the photosynthetic process. Through the courtesy and cooperation of the staff of the Department of Terrestrial Magnetism, arrangements have been made to produce radioactive carbon which may be used to trace the reactions of carbon dioxide in the leaf.

Apparatus and methods have been developed during the past few months to make measurements with radioactive carbon dioxide. The equipment has now been assembled at the radiation laboratory of the Department of Terrestrial Magnetism, ready for the proposed investigations. It is hoped that a clearer conception may be gained of the processes by which leaves absorb and utilize the carbon dioxide of the air.

DETERMINATION OF THE ABSORPTION COEFFICIENTS OF CHLOROPHYLL

It has been evident for some time that an accurate check on the absorption coefficients of the chlorophyll components was necessary, and this has now been carried out by Dr. Gordon Mackinney. The work has involved many problems

of preparative procedure, possible additional components, and degradation products, and finally considerable analytical work before the check could be considered adequate.

Although no new method is used, there are some minor modifications and points of interest which, it is believed, greatly simplify the preparation of the two components. They are necessarily treated here with brevity. The most valuable step in the Willstätter-Stoll procedure, namely, the precipitation of the chlorophyll from petroleum ether solution, may now be consistently carried out rapidly. This is accomplished by a thorough scrubbing of the petroleum ether phase (containing admixtures of acetone and methanol). This is allowed to flow by gravity through a narrow tube dipped 5 to 10 cm. below the surface of water, half filling a separatory funnel of suitable size. The rate of flow is controlled to prevent emulsion formation, and the chlorophyll is frequently precipitated in 3 to 5 washings. Low-boiling petroleum ether is not needed, a fraction (b. 30–70° C) serving the purpose excellently. Starting therefore with a charge of 0.5–1 kg. of leaf meal, one may readily precipitate a few grams of chlorophyll and commence drying it in a desiccator within 3 hours.

Separation of the chlorophyll components by solvent partition is tedious and leads to uncertainty if traces of degradation products are present. This is the cause of most of the discrepancies in analytical results. The Tswett adsorption column eliminates most of this difficulty. Many adsorbents will give fair separation of the blue chlorophyll *a*. Frequently, however, the *b* component is too strongly adsorbed and cannot within reasonable time be separated from the last traces of *a*, and from other impurities. It is noteworthy that the moisture content of the adsorbent markedly in-

fluences the adsorption, particularly of the carotenoids still present as impurities. Thus it was found possible on talc, neutral magnesium citrate ($5\text{H}_2\text{O}$), inulin, and some other adsorbents to duplicate the chromatograms as a result of which a third component of chlorophyll has been postulated in the literature. When, however, an aliquot of the same pigment mixture was adsorbed on a column of magnesium citrate ($7\text{H}_2\text{O}$), or inulin which had not been thoroughly dried, the results were quite different. The two chlorophyll components were found in their expected positions, and below them less strongly adsorbed was a yellow zone of xanthophyll. The same chromatogram could be obtained on the drier adsorbent merely by changing the solvent, substituting benzene or dichloroethane for the original petroleum ether. The green zone of the "third" chlorophyll component was therefore due to adsorption of the blue chlorophyll *a* in the same region as certain of the carotenoids.

Because of difficulties in preparing and recovering large quantities of inulin, it was found simplest to remove most of the chlorophyll *a* with a cheaper adsorbent, such as the magnesium citrate, and to reserve the inulin for the *b* separation. After separation of most of the chlorophyll *a*, on the citrate, the *b* is eluted and reabsorbed on inulin. When the chlorophyll *a* has been reduced to approximately $\frac{1}{4}$ to $\frac{1}{3}$ of the total *b* present, it is possible on a Tswett column

of inulin to obtain complete separation of the two components. Several variations were tried with apparently no effect on the end product.

The separated components are readily precipitated from petroleum ether and thoroughly dried over phosphorus pentoxide. The phase test is then, in both cases, of several minutes duration, but the yellow phase of chlorophyll *a* is exceedingly sensitive to traces of water, which causes it to become markedly more transitory.

The components thus prepared were analyzed for nitrogen and ash, and their absorption coefficients were determined. The leaf sources used were maize, wild oats, alfalfa, spinach, and *Heracleum*. A small sample of *Chlorella* was examined to determine that the two components were identical with those of higher plants.

A detailed account of the absorption spectra will be published. It may suffice here to indicate the approximate positions of the two main absorption bands and their absorption coefficients in acetone solution. These are, for chlorophyll *a*, *ca.* 6630 Å 85, *ca.* 4300 Å 106; for chlorophyll *b*, *ca.* 6450 Å 53, *ca.* 4550 Å 147. The coefficients are given in liters per gram-centimeter, with logarithms to base 10. The values given should not be modified greatly by inclusion of additional samples, as the mean deviations of the above-listed average values are of the order of 1 to 2 per cent.

THE QUANTUM EFFICIENCY OF PHOTOSYNTHESIS

ROBERT EMERSON AND CHARLTON M. LEWIS

The efficiency with which living cells reduce carbon dioxide to carbohydrate has been found to depend on most of the environmental conditions recognized as physiologically important. There is evidence that optimal adjustment of any one factor depends somewhat on other factors, but it has been necessary to make

arbitrary choices in regard to certain factors, in order to study the influence of others. The factors under consideration fall naturally into three groups: the conditions of growth of the cells, the conditions under which photosynthesis is measured, and the technique of measurement.

In studying the efficiency of photosynthesis, liquid cultures of the unicellular green alga *Chlorella* are grown to a suitable density, harvested, washed, and subjected to measurements of photosynthesis in light of known energy content. Light exposures for measuring photosynthesis are alternated with dark periods for measuring respiration. In correcting the measured photosynthesis for respiration, it is assumed that the respiration continues undiminished during the light exposures. The apparent efficiency of photosynthesis was found to depend greatly upon the length of the periods of darkness and illumination, and also upon the method of computation of the respiration correction. There seemed to be no reason, on the basis of existing knowledge, for attributing greater significance to efficiencies obtained with one particular system of timing and computation than with another. The timing schedule used by Warburg and Negelein (*Zeitschrift für physikalische Chemie*, vol. 102, p. 236, 1922), alternating ten-minute periods of light and darkness, was therefore adopted, as well as their method of computing the respiration correction. It may be anticipated that the values obtained on this basis will prove to be proportional to the actual efficiencies, even though perhaps not equal to them. Both the measurement and the method of computation depend upon assumptions which demand experimental verification. However, it was felt that the first objective of this project should be the delimitation of the culture conditions required for the production of cells capable of high photosynthetic efficiency.

The temperature, the intensity and spectral distribution of the light over which the cells are grown, the composition of the culture medium, and the age of the culture, all appear to exert measurable influence upon the efficiency of photosynthesis. Particular attention has been devoted to the medium, because

other investigators have not specified satisfactory standards for this. Warburg and Negelein (Berlin-Dahlem) prepared their medium by diluting stock solutions of the usual nutrient salts with tap water. No calcium was added, analysis showing it to be present in the tap water. Rieke (Baltimore, Maryland; *Journal of Chemical Physics*, vol. 7, p. 238, 1939) used the same salts, and in the same concentrations, but added calcium nitrate. In both instances, efficiencies of 4 quanta per molecule of carbon dioxide were obtained, but we found that if either of these media was prepared in the ordinary distilled water of this laboratory, considerably lower efficiencies were obtained. Thinking that Rieke might possibly have followed Warburg and Negelein in using tap water, we substituted tap water from Baltimore in preparing his medium, and obtained efficiencies comparable with his values. We have since learned that Rieke prepared his medium in water distilled from a tin still, so the use of tap water from Baltimore is of no significance beyond showing that the medium in question will give high photosynthetic efficiency if it is prepared in water from a suitable source. But tap water is not always suitable for the growth of algal cultures, and even ordinary distilled water is not uniformly satisfactory. We prepared a culture medium similar to Rieke's in water from seven different sources, and found efficiencies ranging in value from 35 per cent to 60 per cent, as shown in the table on page 120. The efficiencies, based on measurements made in sodium light ($\lambda=589$ m μ), are expressed in percentages, and also in number of quanta absorbed per molecule of carbon dioxide reduced, as well as the reciprocal of this, the number of carbon dioxide molecules reduced per quantum absorbed. Though the latter form of expression is more correctly the quantum yield, we have followed the practice of

others writing on photosynthesis in referring to the quantum yield as the number of quanta per molecule of carbon dioxide, because the reciprocal is always a fractional number. More than one quantum is required to reduce one molecule of carbon dioxide. It is more convenient to express the yield in percentages, but this implies an assumption concerning the amount of energy stored per unit quantity of carbon dioxide assimilated. The figures in the table are based on Warburg and Negelein's assumption that the carbon dioxide is reduced directly to carbohydrate, and that the energy stored in the assimilation

water, or in commercial distilled water, the highest value shown in the table.

We are indebted to Messrs. Arnon and Stout, of the Laboratory of Plant Nutrition of the University of California at Berkeley, for samples of the stocks of micronutrients which they have found to be important in the nutrition of higher plants. The stock solution designated as A5 contains elements which they recognize as essential: boron, zinc, copper, manganese, and molybdenum. The one designated as B6 contains elements regarded as of possible significance for higher plants: chromium, nickel, cobalt, tungsten, titanium, and vanadium. The

PHOTOSYNTHETIC EFFICIENCY OF CELLS GROWN IN THE SAME CULTURE MEDIUM PREPARED IN WATER FROM DIFFERENT SOURCES

Water	Efficiency of photosynthesis (per cent)	No. quanta per molecule of CO ₂	No. CO ₂ molecules per quantum
Baltimore tap water.....	50.4	4.37	0.229
Searsville lake water.....	41.8	5.26	0.190
Laboratory tap water.....	43.8	5.02	0.199
Residue of glass still.....	44.0	5.00	0.200
Commercial distilled water.....	60.0	3.70	0.270
Laboratory distilled water.....	37.0	5.90	0.170
Glass-distilled water.....	35.0	6.30	0.160

of a given amount of carbon dioxide is equal to the heat of combustion of an equivalent amount of carbohydrate to carbon dioxide and water.

The low efficiency shown for the cells grown in medium prepared in glass-distilled water appears to be due to the relative freedom of this medium from traces of heavy metal impurities present in the tap waters. If traces of the proper elements (following current usage, we shall refer to them as micronutrients) are added to the glass-distilled water medium, cells grown in this medium show an efficiency of about 70 per cent (3.2 quanta per molecule of carbon dioxide) instead of the 35 per cent shown in the table. The efficiency obtained by adding the micronutrients therefore surpasses that obtained with cells grown in tap

proportions in which these micronutrients are used have been published by Arnon (*American Journal of Botany*, vol. 25, pp. 322-325, 1938). We have found that the elements in the A5 solution are responsible for most of the improvement in efficiency of the cells grown in glass-distilled water medium. The elements in the B6 solution, whether added alone or in combination with A5, produce a much smaller but still definite increase in photosynthetic efficiency.

Efficiencies as high as are obtainable by direct addition of the micronutrients to the glass-distilled water medium are also obtainable by adding 5 times the usual amount of iron (as ferric sulphate), and omitting the A5 and B6 solutions. Evidently the ferric sulphate contains micronutrients as impurities in sufficient

quantities so that the requirements of the cells can be met without raising the iron itself to toxic concentrations. We have found ferric sulphate to be superior to the ferrous sulphate generally specified.

Evidence that impurities present in the ferric sulphate in very small concentrations are responsible for the improved efficiency obtained with the 5-fold iron concentration is to be found in the dependence of efficiency upon the age of the cultures. When they are still young, and before the growth has become dense, the efficiency is only slightly influenced by the iron concentration. As the cultures grow older, the efficiency of those to which the ordinary amount of iron has been added drops rapidly, while those which contain the 5-fold iron concentration maintain or even improve their efficiency. In both cases there is sufficient iron to permit an abundant growth, and where the smaller amount of iron is added, then only the addition of micronutrients is necessary to maintain a high level of efficiency as the growth progresses. The increased iron is therefore not in itself a satisfactory explanation for the difference in behavior. However, the presence of micronutrients in the ferric sulphate affords a reasonable explanation of these observations.

The possibility that the iron present as an impurity in tap water could be responsible for the high efficiencies of cells grown in certain tap waters may be ruled out because of the low iron content of two of the tap waters which have been found to produce efficient cells. Warburg and Negelein found the iron concentration in their tap water to be 10^{-6} molar, or only one-tenth of the iron added as ferrous sulphate. The Baltimore City Water Department furnished us with figures for the iron content of the Baltimore tap water, showing that here also the iron added as impurity in the tap water was only a small fraction of that added directly in the preparation

of the medium. It must therefore be concluded that the high efficiencies obtained with cells grown in these tap waters are due to impurities other than the iron they contain.

It was hoped that the importance of micronutrients for photosynthetic efficiency might be more clearly demonstrated by using iron free of other heavy metal impurities. Arnon and Stout kindly furnished us with a sample of ferrous tartrate solution carefully purified of other heavy metals. We found that the addition of an equal amount of iron as ferrous tartrate, instead of commercial ferric sulphate, to the medium in glass-distilled water reduced the efficiency nearly 50 per cent. It could be greatly increased by the addition of the micronutrients contained in the A5 and B6 solutions, but failed to equal the efficiency of the cultures with 5-fold iron, or with micronutrients added to the single concentration of iron as ferric sulphate. The interpretation of these experiments is complicated by the possibility that the iron in different forms may not be equally available to the living cells. It is also possible that the larger amount of iron may improve the effectiveness of certain of the micronutrients, or decrease the toxicity of some. We have no reason for thinking that the ideal combination of concentrations of iron and micronutrients has been attained, and more detailed experiments along this line might be expected to yield further improvements in efficiency.

The medium which we find satisfactory for producing cells having a uniformly high efficiency of photosynthesis contains the following concentrations of nutrient salts in water redistilled from an all-pyrex still:

MgSO ₄	0.0100 molar
KNO ₃	0.0125 molar
KH ₂ PO ₄	0.0090 molar
Fe ₂ (SO ₄) ₃	0.000025 molar

Calcium is supplied by adding to each liter of medium 1 ml. of a suspension of calcium carbonate containing 1 mg. per milliliter. Merck's reagent grade chemicals are used.

High efficiency of photosynthesis depends on proper choice of illumination for the growth of cultures, as well as on suitable culture medium. We have followed Rieke's practice of growing the cultures over ordinary frosted 100-watt tungsten filament lamps, a single bulb being placed below each bath accommodating four cultures. The cultures are grown for 5 to 10 days at a distance of 20 cm. from the lamp, and then for 3 days at a distance of 30 cm. This reduction in intensity just before harvesting appears to be important in obtaining high efficiencies. In our experience, more intense illumination, as for instance from four 60-watt lamps at 10 cm., results in faster growth of cultures but lower efficiency of photosynthesis. A temperature of 15° to 20° C is favorable for the growth of efficient cells. Cultures grown at 10° have been found to give somewhat lower efficiencies, other conditions remaining the same.

The conditions under which photosynthesis is measured also influence the efficiency obtained. A temperature of 10° C appears to be close to the optimum, efficiencies measured at 0° and at 20° being only about half as great. Although photosynthesis at high light intensity is independent of carbon dioxide concentration down to less than 0.5 per cent, maximum efficiency is not obtained unless about 5 per cent carbon dioxide is provided. The light intensity used for measuring efficiency of photosynthesis must of course be so low that it is the principal limiting factor. We have found intensities of about 0.03 calorie per square

centimeter per hour (350 ergs per square centimeter per second) to be satisfactory. While there is a definite tendency for the efficiency to be higher at lower intensities, the photosynthesis is so nearly a linear function of the light intensity that substantial improvements in efficiency cannot be expected by going to still lower light intensities.

The foregoing paragraphs emphasize the importance of better standardization of culture technique if satisfactory comparisons of the efficiency obtained by different methods of measurement are to be made. The yield of 4 quanta per molecule of carbon dioxide has heretofore been regarded as close to the maximum thermodynamically possible, and many students of the subject have used this figure as a basis for considerations of the reaction mechanism. This has hitherto been the highest published value, and, as set forth in our report of last year, the maximum value is of primary theoretical interest. But it remains to be shown that such high yields are indeed a characteristic of the photosynthetic process, rather than of a particular method of measurement. Attempts made in other laboratories to confirm these high yields by different methods of measurement have so far been unsuccessful.

By adhering to the culture conditions described in this report, we have found it possible to obtain yields of 3 quanta or less. It is felt that such high efficiencies must raise the suspicion that some of the assumptions upon which the method of efficiency measurement developed by Warburg and Negelein rests may be incorrect. Abundant experimental evidence that this is the case has accumulated in the course of our work. The testing of these assumptions will be our next objective.

INVESTIGATIONS ON THE CAMBIUM AND ITS DERIVATIVE TISSUES

I. W. BAILEY

The work in this field is continuing to progress along two main lines, (1) *extensive* surveys of the comparative anatomy of a wide range of representatives of the vascular plants, and (2) *intensive* investigations of the ontogenetic development of the vascular and other tissues in specific plants. Investigations of the former type are essential not only in securing a clearer picture of the salient trends of evolution and of structural specialization in the vascular plants, but also as a means of obtaining more comprehensive and reliable information regarding the functional activities of various plant cells and tissues. Investigations of the latter type are indispensable in interpreting and verifying the results secured by the former method of attack.

It is evident that future progress in this broad field of cytological, histo-

logical, and anatomical investigations is dependent upon closer cooperation between workers in different institutions. Unnecessary duplication of effort may be avoided and progress accelerated by voluntary integrated programs of research. The Carnegie Laboratory at Stanford University provides an unusually favorable environment for contacts between Eastern and Western investigators. Thus, during the current summer, Professors Wetmore and Bailey of Harvard, Goodwin of Rochester, and Esau, Crafts, and Foster of California have had numerous conferences and discussions which have provided the basis for concatenated attacks upon fundamental problems of ontogeny and tissue differentiation. Investigations on the cambium and its derivative tissues must be integrated with those upon the primary tissues and vice versa.

EXPERIMENTAL TAXONOMY

JENS CLAUSEN, DAVID D. KECK, AND WILLIAM M. HIESEY

The volume written on the experimental results of transplanting individual plants to different climates over a period of years from 1922 to 1938, mentioned in Year Book No. 37 (1937-1938), page 218, has been submitted for publication. In order to complete this report, much time was spent on cytologic, taxonomic, and statistical research. Not only the immediate physical changes observed have been recorded in this report, but also an analysis of the significance of the reactions in terms of relationship and evolution. Boundaries of the species and of the subunits within the species have been more clearly defined on the basis of the morphological, geographical, and cytogenetical data in coordination with the transplant results.

Taxonomic revisions have been found necessary in *Potentilla* of the Rosaceae, in *Achillea* and *Artemisia* of the Compositae, in *Zauschneria* of the Onagraceae, and in *Penstemon* of the Scrophulariaceae. The chromosome numbers of nearly 400 plants were determined in these and other genera. These represent more than 60 species and 100 taxonomic-ecologic units.

CYTOLOGICAL DIFFERENTIATION WITHIN SPECIES COMPLEXES

The basic chromosome number in *Potentilla* has long been known to be 7. *Potentilla glandulosa* Lindl., a very important member of the transplants, and its allies, *P. arguta* Pursh and *P. rupestris* L., encircle the northern hemisphere with-

out change in chromosome number, which is 7 pairs without known exception. A similar cytologic regularity has been found in *Sisyrinchium bellum* S. Wats., of the Iridaceae, which occupies the area from the shores of the Pacific to the summits of the Sierras and the Great Basin beyond, always with 16 pairs of chromosomes. *Viola adunca* Smith is equally stable, having 10 pairs of chromosomes from the Pacific coast to alpine situations in the Rockies.

The *Potentilla gracilis* complex, in number of individuals second only to *P. glandulosa* in the transplant experiments, presents quite another chromosomal situation. The individual species of the complex have varying chromosome numbers (with perhaps a single exception), and these are very high. *Potentilla gracilis* Dougl. has the greatest variation, with the somatic number varying from about 56 to 109 (octoploid to almost 16-ploid). This extreme amount of cytological variation occurs within the central Sierra Nevada in what is recognized as a single taxonomic subspecies, although this is differentiated into several altitudinal ecotypes. The chromosome number varies even within the population, as in a meadow near the mid-altitude transplant station, where forms have been found with 63, 84, and 101 to 109 chromosomes. Ecotypes are rather well differentiated in *P. gracilis* in the Sierra Nevada irrespective of the chromosomal variation. There is, however, a tendency for the forms from higher altitudes to have fewer chromosomes.

The same situation exists but with less extreme variation in *P. diversifolia* Lehm., *P. flabelliformis* Lehm., and *P. pulcherrima* Lehm., high-alpine, Great Basin, and Rocky Mountain members respectively of the *gracilis* complex. Apparently the only cytologically regular member of the complex is *P. pectinsecta* Rydb., a species of the arid Great Basin, which has 21 pairs of chromosomes. The

cytological irregularity of the others is presumably associated with frequent apomixis, a nonsexual method of propagation. Field evidence suggests that sexual reproduction is also probable.

A similar chromosomal variation was discovered in the *P. Drummondii* complex, including *P. Breweri* S. Wats., with the number of chromosomes ranging from $2n$ = about 64 to 108, and with irregular distribution of chromosomes to the sex cells.

In the genera *Horkelia* and *Ivesia*, related to *Potentilla*, Dr. Åke Gustafsson, of the Institute of Genetics, University of Lund, a guest at this laboratory for a number of weeks in 1938, found that the basic number of chromosomes was 14 instead of 7. All species investigated had 14 pairs of chromosomes except two, which had 28 pairs. Most of the species in these genera were collected in the field and investigated. Their habitats ranged from the immediate coast to alpine peaks at 12,500 feet altitude, but both the tetraploid species were coastal. The difference in basic chromosome number between *Potentilla* on the one hand, and *Horkelia* and *Ivesia* on the other, indicates that the 39 species of the latter genera have evolved independently from *Potentilla*. This investigation is the subject of a paper in preparation by Gustafsson.

Cytological aid has clarified the taxonomic situation in the subsection *Proceri* of *Penstemon*, in which the specific lines are very difficult to draw on the basis of morphology and distribution alone. While the majority of species are diploid ($n=8$), a number of tetraploid and two hexaploid species have been discovered. In this complex the greatest morphological and cytological diversity was found in the area surrounding the Blue Mountains of northeastern Oregon, indicating that here is an evolutionary center for this group.

It has been determined that the west-

ern American forms of the *Achillea millefolium* and the *Artemisia vulgaris* complexes are indigenous species distinct from the European members of each. These complexes are of special interest because of their worldwide distribution, coupled with their ability to develop forms adapted to extremely different environmental conditions. It is of importance to attempt to trace the evolution of groups that have been able to populate areas so extensive and environments so diversified.

The most widespread American yar-row is *Achillea lanulosa* Nutt., a tetraploid ($n=18$). It has developed a series of marked altitudinal ecotypes from the Sierras to the Rockies. The California Coast Ranges are occupied by the hexaploid *A. borealis* Bong. ($n=27$), which extends northward to Alaska and has developed equally marked ecotypes. The European *A. millefolium* L. has the same chromosome number but is morphologically distinct, and the two do not interbreed. No diploid forms have been found. From present information it appears that the center of origin of this complex should be sought in the western United States, where the cytological and morphological diversity is the greatest.

Members of the *Artemisia vulgaris* complex present a still more complex picture. The maritime region from central California to British Columbia is occupied by a tall diploid, *A. Suksdorfii* Piper ($n=9$), which is so limited in its adaptability that it cannot survive even at the mid-altitude station at 4500 feet altitude. Another native of smaller stature, *A. ludoviciana* Nutt. ($n=18$), occupies the drier and higher regions from subalpine and alpine altitudes in the Sierras eastward to the Great Plains. It has developed ecotypes to fit various altitudes and environments in this area. A third species, *A. Douglasiana* Bess., combines the characters of both and occupies the territory between them. It

is intermediate in its reactions at the transplant stations and has 27 pairs of chromosomes, which is the sum of the numbers in *Suksdorfii* and *ludoviciana*. The two latter meet near the coast in the Columbia River region, suggesting the possibility that *A. Douglasiana* arose by doubling of the chromosomes in a hybrid between them. Apparently *A. Douglasiana* has not developed any clear-cut ecotypes as yet (a possible indication of youth), but it is very adaptable, as might be expected if it arose by adding the chromosomes of a maritime and an interior species.

Another 27-chromosome species, *A. Tilesii* Ledeb., occupies the coastal region from northern Washington to Alaska and the Aleutians. The European *A. vulgaris* L., with which all these were previously identified, is morphologically distinct and has but 8 pairs of chromosomes. Other members of this complex remain to be investigated, but it appears that in this case also the center of diversity is to be found in the western United States.

Cytological investigations in the *A. tridentata* complex, while little more than begun at present, prove that the sagebrush is not one taxonomic species with several subspecies, as it has been regarded recently, but a complex of species that are members of a polyploid series. The first three forms of the complex to be investigated cytologically, representing three different taxonomic units, are diploid, tetraploid, and octoploid. One of these was the diploid *A. Bolanderi* Gray ($n=9$), endemic in the desert area around Mono Lake, California; another, the octoploid *A. Rothrockii* Gray ($n=36$), only a few miles distant in the subalpine and alpine regions of the Sierras. Accordingly, one evolutionary center for the sagebrush may be anticipated to be in this general area. It remains for the taxonomy of this group of plants to be re-examined in connection with cytological investigations.

A similar problem has been uncovered in the *Aster adscendens* complex in California, where the Great Basin form is diploid ($n=8$), and the morphologically and physiologically distinct Sierran ecotypes are tetraploid ($n=16$).

These examples taken from the investigations of the past year indicate that along the Pacific slope chromosome differences are very common between plants of closely related species, and that they are commonly associated with differences in ecological requirements of the plants. But there is no rule as to where the cytologically primitive forms are found. In some instances they are near the sea, in others in the interior arid basins, and in still others near the mountain peaks.

CAUSES OF DISCONTINUITY IN NATURE

Experiments on plants of many groups and from many environments, differing widely in their cytological patterns, indicate that they are in balance with their native environment. Furthermore, this balance is an inherited characteristic. We find that quite irrespective of their cytological situation many groups of plants along the Pacific slope have developed parallel series of ecotypes, ecospecies, or both, in the same series of environments. These ecologic units are found to be rather accurately adjusted to the conditions in the zones which they occupy. A plant may succeed in a new environment only if its heredity enables it to accommodate its physiologic processes to the complex demands of the new environs and to compete with other forms. This limitation prevents most plants from the wild from truly succeeding outside their natural distribution.

Not only must a plant be in equilibrium with its environment in order to succeed, but its entire gene activity must be in balance. Even a single pair of sublethal genes may completely disturb the physiological processes. Possibly

thousands of genes interact in each individual, all influencing it slightly in one direction or another. Of necessity all processes regulated by them must be synchronized in the proper order and adjusted to the environmental conditions if the plant is to succeed. In this respect each ecospecies represents a different equilibrium. When two ecospecies exchange their genes, the balance is upset.

In view of these exacting requirements it is understandable that nature is discontinuous and that evolution is a slow process. It is to be expected that in a system so intricately balanced only a certain number of equilibria are possible under given conditions, and that a certain inertia against changes may be experienced. The very nature of the double demands of internal balance and fitness to the environment is evidently the most important cause of the apparent discontinuity in nature.

The experimental investigation of the discontinuities in nature has established their presence both between and within species. It remains to be investigated whether the genetical differentiation of plants to fit different environments is always discontinuous even within the species, or whether in some species gradual transitions exist from one ecotype to another, keeping pace with the gradual climatic changes that are found in such transects as that represented by the transplant stations of the Carnegie Institution across the west flank of the Sierra Nevada.

OTHER INVESTIGATIONS

Cytological studies in the genus *Viola* have been continued by Dr. Clausen. A taxonomic treatment of the genus *Penstemon* has been prepared by Dr. Keck for Dr. T. H. Kearney's forthcoming "Flora of Arizona." Through the kindness of the Department of Botany of the University of California, Dr.

Hiesey used its special equipment for determining transpiration values of different altitudinal races of *Potentilla gracilis* under controlled moisture, temperature, and light conditions.

The cytological program of the year

was materially advanced through the able assistance of Miss Suzanne Ravage, who made thousands of slides and was responsible for an appreciable number of chromosome counts in *Potentilla* and other genera.

DESERT INVESTIGATIONS

FORREST SHREVE, T. D. MALLERY, EDITH B. SHREVE, AND WILLIAM V. TURNAGE

FIELD INVESTIGATIONS

The preparation of a "Flora of the Sonoran Desert," in the hands of Dr. Ira L. Wiggins, of Dudley Herbarium, Stanford University, has made substantial progress during the year. Owing to the scattered location of early collections from the area, and the lack of recent revision of many of the important groups of plants, it has been necessary for Dr. Wiggins to examine much generously loaned herbarium material and to make a careful study and revision of many genera.

As work on the Sonoran Desert draws to a close, a companion investigation of the botanical features of the Chihuahuan Desert has been begun. This area occupies the plateau region of northern Mexico and adjacent parts of Texas and New Mexico. It differs from the Sonoran Desert in its higher altitude, in its wholly continental position, and in many features of physiographic development. The few and meager contributions to knowledge of the biological features of the area indicated a field of work interesting both in itself and in comparison with the Sonoran Desert.

Investigation of the flora of the Chihuahuan Desert will be carried out through cooperation with the Arnold Arboretum of Harvard University. Dr. I. M. Johnston will participate in field work and prepare a flora of the area. The complexion of the flora is well known through early collections, but large areas and numerous mountain ranges have had

no botanical exploration. The geographic ranges and distributional limits are poorly known even for some of the commonest plants.

In the late summer of 1938 seven weeks were spent in northern Mexico by Dr. Shreve, Dr. Mallery, and Dr. Johnston. A wide survey of the area was necessary at the outset in order to determine the extent of desert of the type characteristic of central Chihuahua, and to set the tentative limits of the area to be covered in the investigation.

The eastern edge of the desert was followed from Piedras Negras to Monclova and Saltillo, east of which line is found the coastal semidesert that has been described by several writers for Tamaulipas and southern Texas. The states of Zacatecas and San Luis Potosí were examined as far south as the city of San Luis Potosí, and in that region parts of the southern boundary of the Chihuahuan Desert were found. The central bolson region was explored in the vicinity of Cuatro Ciénegas, Parras, Viesca, and Zaragoza, in Coahuila. The western limit of desert was determined in the region west of Mapimi, Durango, and several elevated basins were visited in northeastern Chihuahua. The most arid regions encountered were in southern Coahuila and in extreme northern San Luis Potosí. In central and southern Coahuila large arid mountain ranges were found which merit thorough exploration. Highly specialized and endemic species appear to be more numer-

ous in these very dry habitats than in the slightly more favorable ones.

Very few of the abundant plants of the Chihuahuan Desert occur in other parts of the North American Desert. Some of the abundant plants are closely related to species found elsewhere. In a few cases great similarity of vegetative form exists between unrelated plants of the different desert areas. In general the plants which have similar systems of adjustment to environment are found in similar habitats throughout the North American Desert, but some striking exceptions to this generalization were found in the field work of 1938.

In the Chihuahuan Desert differences of elevation have less influence on the makeup of the vegetation than in the Sonoran Desert. Several common plants occur through a vertical range of over 3000 feet. Two plants which are almost equally abundant in the two deserts are the creosote bush (*Larrea*) and the ocotillo (*Fouquieria*), and each of these is found through a remarkable range of altitudes. In the Sonoran Desert *Larrea* is dominant from sea level to 3000 feet; in west Texas it is common at 4000 feet; in northern San Luis Potosí it forms extensive pure stands between 5500 and 6000 feet; and in northern Zacatecas it occurs in very open formation with a thin sod of grasses at 7000 feet. A better knowledge of these plants may demonstrate a relation between their capacities for wide geographic distribution and for exceptional vertical ranges.

Shorter field excursions were made during the year along the northern edge of the Sonoran Desert in Arizona to determine the upper limits of certain shrubs and succulents and to study the conditions found where the desert meets chaparral or grassland. East of the Bradshaw Mountains the desert gives way rather abruptly to chaparral between 3500 and 4000 feet, according to slope exposure. West of the Bradshaw Mountains there are large areas in which

desert and chaparral are separated by grassland, now sorely depleted by overgrazing. It has been possible to correlate the difference with character of soil and with seasonal distribution of rainfall. Invasion of the grassland and chaparral by larger desert perennials is very slight, but at least 20 smaller perennials range nearly to the limits of the mesic pine forest.

Dr. Shreve was asked by Dr. Thomas H. Kearney to prepare a chapter on the vegetation of Arizona for publication in the "Flora of Arizona" which is being written by Dr. Kearney and Mr. Peebles. In order to be able to give a satisfactory treatment of the Great Basin type of desert which occupies the northeastern corner of the state, Dr. Shreve accompanied Mr. Peebles in the spring of 1939 on a trip of 1100 miles through that part of the state.

Investigations dealing with the classification and distribution of plants are concerned almost entirely with the mature or adult forms. From the ecological standpoint great importance attaches to each of the stages in the life cycle of the plant, and particularly to the early ones. During the course of field work in the Sonoran Desert attention has been given to seeding habits, modes of dissemination, and the abundance and character of young individuals of the dominant perennials. During the past two years Dr. Mallery has supplemented field observations with a study of 90 annuals and 94 perennials under greenhouse and outdoor conditions. Nearly all this number were raised from seed, thereby giving a knowledge of the temperature and resting requirements, and of the percentage of germination for small quantities of seed. With optimum temperature and moisture of the soil the seeds of the great majority of desert perennials germinate within 6 to 18 days. Delayed germination is common in the leguminous trees and shrubs and also in certain highly xeric forms, including *Nolina*, *Randia*,

and *Holacantha*. Various methods of cutting or scarifying leguminous seeds result in prompt germination. The time required for germination of unscarified seeds is very irregular. Seedlings from 1 to 2 years of age are removed to the open and, after a few weeks, subjected to natural conditions. Observations are then made on their rate of growth, approach to adult type of foliage, development of spinescence, enlargement of cortex, exfoliation of bark, and other features.

It is customary to refer to a large number of desert plants as being highly specialized in form and structure. On most of these plants so little anatomical and physiological work has been done that the functional and survival value of their peculiar features is largely a matter of conjecture. Of particular interest are the features which recur in a number of unrelated genera, as is true of the basal enlargement of the trunk, well known in the copal and "elephant tree." An investigation of a similar feature in *Jatropha* has been begun by Mr. Richard A. Popham, of Ohio State University, who is spending three months at the Desert Laboratory.

ENVIRONMENTAL CONDITIONS

The study of distribution of rainfall in relation to altitude, topography, and storm movements, which has been under way for several years, has been completed and the results are in an advanced stage of preparation for publication.

For the past 18 months readings of runoff have been made on three very different soils, a heavy silt, a sandy loam, and a light but very stony loam. The differences observed are correlated with the distinct types of vegetation found on the three soils. Generalizations can be drawn from the work only after the accumulation of a longer series of data.

Readings of runoff and soil moisture taken for 8 years on the heavy silt have been interpreted by Mr. Turnage in terms of the physical properties of the layers of soil encountered in sampling. Only the first 1 or 2 feet are wetted ordinarily by the rains. The lower levels remain at much the same moisture content throughout the year, but the several levels do not have identical amounts. Each of the lower layers remains approximately at the wilting percentage throughout the year, varying from 8 to 16 per cent. These variations correlate very well with the texture of the soil, the layer with the highest wilting percentage being a veritable "clay pan" in an otherwise loamy soil. The clay pan is about 6 inches thick and lies at a depth of approximately 4 feet. It is probably the result of leaching of the clays downward in the process of infiltration, and their deposition at the maximum depth of infiltration. Only once in the period of study has infiltration occurred to this depth.

A metal tower presented by the University of Arizona was erected in the garden, lying at the outer edge of the Santa Cruz flood plain, and has given opportunity to study conditions at four levels. Continuous records of air temperature have been taken at 5 and 45 feet, and for several long periods readings of humidity, wind, and evaporation have been taken at 3, 22, and 45 feet. Interest in these data is mainly in connection with temperature inversion and the influence of wind on evaporation.

The importance of evaporation in connection with the water relations of plants has led to many investigations at the Desert Laboratory over a long period. During the year Mr. Turnage has cooperated with Mrs. Shreve in her work with porous evaporating surfaces and has also investigated some of the conditions determining evaporation from a so-called "free water surface." Hourly evaporation was measured from pans 12.5 cm. in

diameter and 6 cm. deep, with pans in shade, in full sun, and alternated between sun and shade. At vertical sun the pan in the shade lost as little as 53 per cent of the amount lost by the pan in the full sunlight. The loss of the third pan in a given hour was largely dependent upon whether its preceding hour had been in sun or in shade, being markedly higher in the former case. The strong influence of solar radiation and the strong lag do not recommend evaporation pans for use in transpiration work. Similar comparisons with the Livingston atmometer in sun and shade showed the water loss to be largely independent of solar radiation, only 5 to 15 per cent of the total loss being attributable to it. Also the lag effect was negligible in the atmometer.

Atmometers exposed on the metal tower at 3, 22, and 45 feet gave average daytime readings in the ratios of 100, 94, and 80 respectively. The daytime temperature and humidity conditions did not differ greatly at the three heights, but a strong wind-velocity gradient apparently explained the difference in evaporation. During the night the rates of evaporation at the three levels were in the ratio 100, 80, and 55. The presence of nocturnal temperature inversion, lowering the temperature and increasing the wet-bulb depression for the lowest instrument, did more than the wind-velocity gradient to account for the difference in the ratios. These results emphasize the importance of careful selection of the height at which an atmometer is exposed, and also indicate that readings taken at long intervals have undergone an automatic smoothing which may obscure important features of the daily march of evaporation.

Some preliminary attempts were made to calibrate the atmometer against the climatic factors in an empirical manner. Direct solar radiation played a minor rôle. At a given wind velocity, evaporation from the atmometer was proportional to wet-bulb depression. Wind

velocity influenced the water loss as much as did humidity, but in an exponential manner. A family of curves was constructed from the data showing the influence of wind at various humidity values, but it was apparent that the difficulty of measuring wind velocity under natural conditions makes it desirable to reconstruct the curves from data gathered under controlled conditions.

PLANT PHYSIOLOGY

The fact that some perennial plants are able to live under arid conditions, while others are not, raises several fundamental questions in regard to the water relations of plants. Do successful desert plants resist to any extent the evaporative force of the air? Do they obtain water from the soil and conduct it to the leaves with more efficiency than other plants? Do they lose water rapidly until a low water content of the soil is reached and then remain dormant? Are there other unknown factors? The answers to these questions have been sought by measurement of water loss from desert plants under different environmental conditions, especially the loss under high and low aridity. Also comparison has been made of the water economy of xeric and mesic plants under identical conditions, although such comparison cannot be carried into conditions of high aridity, beyond the limits of endurance of the mesic plant.

Experimental attack on the water economy of the plant necessitates measurement of soil moisture and of atmospheric conditions, particularly wind velocity, air temperature, and humidity. Methods are available for measurement of soil moisture which are accurate enough for the purpose. Various attempts have been made to devise an instrument which will give a collective measure of the atmospheric conditions which are operative in the water loss of the plant. Open pans of water and va-

rious types of paper and porous clay surfaces have been used for the measurement of evaporation in conjunction with transpiration readings. The most convenient and widely used appliance is the Livingston atmometer, on which, however, much adverse criticism has been passed.

Owing to the convenience and adaptability of the atmometer and the rather extensive transpiration literature based on its use, Mrs. Shreve has undertaken an investigation of the behavior of the atmometer under a wide range of conditions and has compared it with other types and shapes of porous clay evaporating surface. These types were selected with a view to answering the criticism of the atmometer that its form departs too widely from that of the leaf.

Work recently published by Mr. Turnage and Mrs. Shreve shows that the water losses of the atmometer which accompany changing wind velocity and wet-bulb depression can be plotted to show definite and regular curves. There is no indication that there are sudden changes in the performance of the atmometer on the attainment of particular intensities of wind or humidity.

Only by the use of an appliance which measures varying rates of evaporation with precision is it possible to secure a norm with which the performance of the plant can be compared. In connection with the work on the transpiration of creosote bush (*Larrea*), cotton, and soy beans, Mrs. Shreve has compared the spherical atmometer with several types of artificial leaf in order to see whether any of these types would provide a better norm than the atmometer. Alundum

disks 2 to 3 mm. in thickness were ground to the shape and size of cotton, creosote bush, and soy bean leaves, with slender stems which were sealed into glass tubes. Groups of 16 artificial leaves were connected with a water supply by tubing and exposed so that they were able to move in the wind. Simultaneous hourly or half-hourly readings of the "artificial plants" were made together with readings of two atmometers. Readings were made in a dark room with nearly constant temperature and humidity and without air movement, in a laboratory room with dull light and small variations of temperature and humidity, in a greenhouse with higher humidity and temperature, in the open in summer and winter, in sun and shade, and at two heights on the metal tower. The entire temperature range was from 40° to 106° F, the wet-bulb depression from 10° to 40° F, and the wind velocity from 0 to 18 miles per hour.

The atmometer readings were correlated with the water losses from each of the artificial plants for the entire series of conditions under which they were run. All amounts were reduced to loss per hour per square centimeter of exposed surface. Graphs were drawn by placing the losses from each artificial plant along the Y axis and from the atmometer along the X axis. Inspection showed a linear relation. Equations were calculated by the method of least squares and fitted to the graphs. The number of observations ranged from 50 to 102, so no adjustment was made for number of observations. The equations and coefficients of correlation are shown in the accompanying table.

Artificial plant	Area of single "leaf" (sq. cm.)	Equation $y = a + bx$	Coefficient of correlation	Standard error
Large disk	32.06	$y = 0.005 + 1.2x$	0.96	0.100
Cotton	30.00	$y = 0.02 + 1.2x$	0.98	0.007
Soy bean	19.50	$y = 0.009 + 1.5x$	0.99	0.008
Creosote, alundum	1.50	$y = 0.02 + 2.4x$	0.99	0.020
Creosote, blotting paper . . .	1.80	$y = 0.02 + 2.6x$	0.99	0.007

The linear form of the relation shows that changes in the atmospheric conditions bring about comparable changes in water loss from atmometer and artificial plant. The varying values of b in the equation show that the actual amount of water loss per unit area varies with size, shape, and manner of exposure. Consequently, for the plant forms investigated, the atmometer may be safely used to measure the evaporative forces of the air when the behavior of one type of plant is being investigated for the changes in its water loss under varied environmental conditions. If, however, the actual amount of water loss per unit area of one plant is compared with that of another type, then either the corresponding artificial plants must be used or the atmometer must be correct according to the equation for the proper forms.

The sun and shade measurements showed that direct solar radiation has a negligible effect on both atmometer and artificial plant. This is an advantage, since it makes possible separate investigation of the effect of radiation on the plant.

Transpiration experiments with creosote bush, cotton, and soy beans have been carried out, in conjunction with readings from two atmometers and the corresponding artificial plants. Measurements of wind, humidity, and temperature were made, material was secured for study of stomatal opening, and determinations were made of water content of leaves, stems, roots, and soil. At present only the data on the creosote bush have been worked up. When the water losses are plotted against those of atmometer or artificial plant, a linear relation is found over only a very narrow range of conditions, and even here there are large irregular deviations from the regression line. These deviations are tentatively taken to be caused by factors peculiar to the plant, which include structure of

the surface as well as physiological changes within the plant.

Work on the osmotic behavior of the parenchymatous tissues of the giant cactus (*Carnegiea gigantea*) was carried on during the summer of 1938 by Dr. Marcel V. Homès, Professor of Plant Physiology in the University of Brussels, Belgium. The aim of the work was to get a better understanding of turgidity, and succulents were chosen as material because of their great variations in volume under natural conditions. Previous work by D. T. MacDougal and Edith B. Shreve has given evidence for such changes and shown the essential features of the swelling process.

The initial experiments were made by use of a dilatometer, designed for magnification of swelling or shrinkage in pieces of tissue of uniform size. The actuation of this apparatus gives evidence of the presence of expansion energy, which is usually called turgidity. From a simultaneous study of swelling by the dilatometer method and by changes of weight, it appeared that (1) the cortical tissue of *Carnegiea* may be lacking in noticeable turgidity during the summer dry season, (2) it becomes turgid after the rains, obviously owing to the intake of water, (3) the intake of water by cortical tissue under experimental conditions *does not* always result in an increase of turgidity. This surprising result seemed at first to be in open contradiction to the accepted idea that turgidity is due to the well-known property of the protoplasm of working like an osmotic semipermeable membrane. Further study of the swelling of cortical tissue under the dilatometer showed that different types of curves could be obtained for expressing the expansion-time relation, depending on the state of the tissue at the beginning of the experiment. On the contrary, the medullary tissue always gave, under such

conditions, the same simple type of curve, probably exponential, and always in agreement with the weight-time curve, a cube root relation existing between the two. In the medullary tissue the energy required to actuate the dilatometer is negligible as compared with the expansion force developed by the cortical tissue.

Later experiments were undertaken in an attempt to explain the diversity of the swelling curves of cortical tissue. The study of osmotic value of sap expressed at different stages of the swelling process, combined with the study of exosmosis at the same stages, led to the well-defined conclusion that in cortical tissue the slow natural desiccation of the dry season is accompanied, among other phenomena, by a marked increase of protoplasmic permeability. A first consequence of this fact is the presence of much *intercellular* dissolved substance in the cortical tissue of *Carnegiea* during the dry season. When the tissue is allowed to swell by immersion in water, there is simultaneously an intake of water, a decrease of permeability, and, as long as possible, an exosmosis. The relative importance of the last processes depends on the previous stage of desiccation and varies in every case. By its particular shape the swelling curve expresses the result of the simultaneous antagonistic processes, exosmosis and decreasing permeability to solutes. If exosmosis is fast enough, the tissue, although immersed in water, never becomes turgid.

Under natural conditions the lack of unlimited space for exosmosis, the constant direction of the water stream, and the slow progress of swelling after rains will result in the early reappearance of enough so-called semipermeability to allow the establishment of turgidity. During the natural desiccation of the dry season the change of permeability results in a very interesting and favorable fea-

ture—the total loss of turgidity without plasmolysis. In this way the tissue is able to undergo advanced dehydration without drying.

The properties of the medullary tissue are very different from those of the cortical tissue, since it does not become as permeable. Consequently the experimental swelling is not accompanied by as much exosmosis and the curve of this process is simple and of constant shape. Knowledge of the difference between the osmotic properties of medulla and cortex explains the behavior of large slices and entire plants of *Carnegiea* under conditions of desiccation. In a transverse slice 1 foot thick the cortical tissue becomes softer and softer on continued exposure, while the medullary tissue retains its turgidity and even sometimes becomes harder. It is probable that owing to its intact "semipermeability" the medullary tissue is able to take up water from the cortex. In a 10-foot specimen dug up at the end of the dry season the medullary tissue was found quite turgid from top to bottom. During the dry season this tissue seems to keep its full vital activity, as do the green external layers, while the cortical tissue seems to serve only as a storage medium for the benefit of the active tissues. Its ability to serve this function is due to its remarkable property of having protoplasmic permeability adjusted to the climatic circumstances leading to dehydration.

The part played by the cell wall in the development of a swelling force has been found important. When a piece of tissue is killed by desiccation or by immersion in a toxic solution, followed by partial drying, it shows a tendency to take up water when immersed. Under such conditions the medullary and cortical tissues show about the same swelling power, as measured by increase of weight. However, the former develops a force sufficient to actuate the dilatometer, while

the latter does not. Thus in the living wet tissue a considerable part of the turgidity of medullary tissue is due to the

cell walls, while in cortical tissue the living contents are responsible for the turgidity.

ECOLOGY

ADAPTATION AND ORIGIN

F. E. CLEMENTS, F. L. LONG, AND
E. V. MARTIN

Adaptation in coastal dunes. The functional studies of adaptation to different habitats in the dunes at Santa Barbara have been completed for publication. The habitats concerned have been mobile and stable dunes, and the foredunes of the strand; for the sake of a wider comparison, other littoral dunes have been taken into account, as well as the Algodones of the Salton Sea. Contrary to the usual view, such aerial factors as wind, humidity, and temperature have proved to be of much less importance than water content and nutrients. The mobile sand is lowest in these two factors and hence constitutes the most xeric situation. Most species are unable to maintain themselves in it, and those that do so are strikingly dwarfed. This is due primarily to the rainless season of six months or more, though the addition of fertilizer is much more effective than water in stimulating growth, the ratio being about 10:1. However, much of this is produced by greater root growth that enables the plant to secure more of the low holard.

The dominants of coastal dunes for the most part are moderate xerophytes, as indicated by their inability to grow in mobile sand, and by the dwarf habit, the presence of much palisade tissue, and especially the devices for reducing the number and size of leaves. They vary much in rate of transpiration, but on the basis of wet weight are all distinctly lower than *Helianthus annuus*. They do not conform to the view that xerophytes under adequate holard transpire more than mesophytes, nor do they increase

the absolute amount of palisade in the driest sites. They demonstrate that a single criterion for determining a xerophyte may be quite misleading and that the total functional and structural performance is essential to an exact analysis. This is tantamount to saying that life forms and habitat forms, like species and communities, are dynamic responses to physical factors and will vary throughout the widest range of these.

Response to holard gradients. In analyzing the respective rôles of water and light in adaptation, it was found that transpiration and growth were closely proportional to the amount of water present. Although this analysis was carried out with thousands of plants in ten replications during successive seasons, it was felt desirable to introduce a new technique for further checking. This comprised the use of larger phytometer cans, 13×22 inches, in three series of 12 cans each. Each of these was divided into two sets of 6; the control was watered frequently to keep the holard above 14 per cent, while the test set received water only when the holard dropped to about 10 per cent, after which it was brought back to field capacity. In a second group of three series, the soil was mixed with a definite holard and no water was added during the runs. The series contained four groups of 6 cans each, with initial water contents of 11, 14, 17, and 20 per cent, and the tests were brought to a close when the 11 per cent holard was reduced to about 9 per cent. The march of the reduction in holard was followed by taking soil samples at depths of 2, 8, 14, and 20 inches from the surface.

The manifold details may be found in

the published paper by those interested, and only the major results can be outlined here. In all the series, a lower holarid resulted in reduced growth in terms of stem diameter, leaf area, and dry weight, and usually in stem height. The rate of transpiration per unit leaf surface ordinarily was modified when about two-thirds of the chresard had been removed. Under both methods, the growth rate was affected by very small differences in water content. Stomata were smaller and more numerous and the leaves thinner with water less available, but the ratio between the palisade and sponge tissues was unchanged. No increase in the rate of transpiration could be detected in plants that had recovered from wilting by comparison with that of the controls, contrary to the results obtained by Tumanov.

Transpiration and weekly increment of dry weight. In the further analysis of the functional phase of adaptation, transpiration, weekly increment of dry weight, and growth have been measured for a number of species under different light treatments at Santa Barbara. The latter comprised a lath-house series from full sunlight to approximately 6 per cent, length-of-day tents with periods of 14, 9, and 5 hours, and large sheds in trackways with intervals of 6 and 4 hours. In addition to sunflower phytometers, a number of long- and short-day species were grown in each of the series.

At the Alpine Laboratory, some 30 transplant species represented by approximately a thousand phytometers are installed at the plains, montane, and alpine gardens. A number of these plants are adapted forms of a particular species taken from the transplant gardens. In other cases, individuals have been moved from their native habitats early in the season, transplanted to containers, and distributed to the various climatic and edaphic habitats, to permit following their growth and adaptation during the

season. In addition, several species were transplanted to cans in 1938, left over the winter in the proper climax, and then distributed to the various habitats early this year before any appreciable growth had been made. Transpiration, stomatal behavior, and growth are determined in the several habitats with the purpose of correlating these with structural modifications as well as physical factors. Later in the summer the phytometers will be brought together in the same habitat in order to evaluate the performance of the ecads independently of the differences in factors.

The weekly increment in dry weight in relation to the leaf area can rarely be secured from the transplant material, partly because of the excessive number of individuals required for a season's run, but chiefly because the plants are too valuable to be destroyed. Hence, for the present series sunflower and rye are being employed, as representing forbs and grasses and as being quite divergent in their temperature requirements. Batteries of each of these have been installed in the three major climatic stations and in several edaphic habitats in each of these.

Ecads and conversions. With a steadily increasing number of ecads and conversions in the transplant garden, it has again become desirable to pay more attention to species and their modifications in nature. This has led to a renewed search for evolution centers where adaptation is especially active. As a rule, these are limited in area and edaphic in nature, but they are also not infrequent in the ecotone between climaxes, notably where the mixed prairie rises to altitudes of 7000 to 8000 feet. Here the fluctuations of the climatic cycle have their most marked effect and, taken in conjunction with small soil habitats (micreces), may bring about the reciprocal modification of related species. This may be illustrated by *Agropyrum smithi*, which in

such situations on the Platte-Arkansas divide may change from sod to bunch habit, from smooth to hairy, and from awnless to awned, to merge with as many neighboring species.

Dune sand is one of the most effective agents for bringing about the inversion of habitats without destroying the plants originally present. A remarkable instance of rapid and extensive evolution of this type is to be found at the northern end of the Santa Monica Mountains, where high winds have swept the sand well up the slopes to produce a new habitat, with corresponding modifications of the dominant species to the number of 25 or more. These forms are for the most part of the dwarf procumbent type produced by the joint action of strong wind and low water and nutrient content. These factors express themselves in recurring series of small differences, with the result that most of the species exhibit a continuous line of ecads, indicating that adaptation operates to produce new forms without the intervention of natural selection.

The method of experimental conversion has yielded an unusually large number of results, owing in large measure to the extensive installations of grasses especially. Most of the genera of the latter under investigation have given from one to several conversions of linneons, and still more of subspecies. Chief among these are *Agropyrum*, *Elymus*, *Poa*, *Festuca*, *Bromus*, *Eragrostis*, *Melica*, and *Stipa*. The two major phylads of the latter have been reconstructed experimentally, rendering it possible to trace the parallel evolution of species and climax associations around the circumpolar region and through the western hemisphere. A single species under two names, *Stipa capillata* and *comata*, extends across Eurasia and North America; as climates have differentiated, it has become adapted to them, and each species thus produced has become the characteristic dominant of a new division of the climax.

A second phylad, *S. sibirica-viridula*, is likewise circumpolar, but is more northerly, with higher water requirements. Hence, its derivatives incline to be seral in nature and are more readily converted, both in nature and under experiment.

Among the genera of forbs employed, *Lupinus* is representative of those of wide extent, great abundance, and marked powers of survival and adaptation. Perhaps no other genus of forbs in western North America equals it in the great number of intimately related ecads. Both over the Great Plains and on the Pacific coast occur an annual and a perennial phylad, those of each life form doubtless stemming originally from a single species covering the entire area. In California, the perennial stock has become differentiated into a coastal, usually dune, series and a montane one, with a corresponding tendency to woodiness. The annual phylad is logically a denizen of warm valleys and desert plains, and in consequence has undergone even greater differentiation because of its ready adaptability. Both of these agree in the fact that the taxonomic division into species is largely based upon the technical character of the distribution of hairs or cilia on the keel of the flower. This proves to be a reversible character, almost as easily gained as lost, and hence one that contributes to the ready conversion of species. As a consequence, it has been possible to trace the continuous phylad in both the annual and the perennial group by combining garden and field results, and the immediate task is the usual one of discovering the complete phylad in nature, as well as re-creating it by experiment.

As would be expected, the conversion of one genus into another, morphologically at least, is much more difficult than with species, but it is far from impossible, and with improved technique may become a familiar matter. Generic conver-

sion is simplest in grasses and composites, where the criterion is often single and technical, and responsive in some degree to the direct action of physical factors. For example, the technical difference of one spikelet at a joint in *Agropyrum* and two in *Elymus* may be reciprocally modified in several species of each genus, while among the *Helianthus* tribe of composites, the nature of the pappus may be altered to combine or separate several related genera.

Paleoecology. The principles formulated nearly a quarter of a century ago in *Plant succession* in organizing the new field of paleoecology have undergone repeated and extended tests at the hands of Dr. Chaney and his students, and appear to meet all the requirements of Tertiary paleoecology in general, though they need further elaboration as to the details. Their extension to the Pleistocene and the Recent has been outlined in *Origin of the desert climax and climate* and in *Environment and life in the great plains*. They are now being extended to the Cretaceous of North America and the Eurasian Tertiary in the expectation that they will permit new interpretations in them as well.

In Asia especially, the major difficulty arises from the relatively small number of fossil floras, while in North America a wide gap must be bridged between the Cretaceous and the Eocene of the interior. Fortunately, the series of climaxes, or clisere, of the two continents is essentially similar, while there is likewise much resemblance between their large fossil floras. A further point in common is the subsidence that produced the great mediterranean sea on each, and the emergence that led to the major climatic and climax zones, the clisere of today. However, a difference resides in the fact that the epicontinental sea extended generally from north to south in North America and from east to west in Eurasia.

When floras are contiguous in time or space and fit into the general pattern of the clisere, the present principles are readily applicable to new continents or periods. But when fossil floras are remote and scanty and the gaps extensive, it is necessary to appeal to phylogeny and to reconstruct genera and climaxes from their descendants. Until recent years, this was difficult if not impossible, but with the strides made in re-creating species through adaptation, it has become feasible to discover the relationships of dominants and to suggest their place in climax and climate.

CLIMATE, CLIMAX, AND CONSERVATION

F. E. CLEMENTS AND E. S. CLEMENTS

Sunspot cycle and drought periods. The discovery in 1920 of a double cycle in sunspots and rainfall for some 23 western states permitted a forecast of relative numbers for the maximum of 1928, which fell within 2 of the number observed. This suggested that sunspots would be high at the next maximum, probably in 1938, and a tentative prediction was made to this effect. This was verified as to number, which was 115, but the rate of change for the two years 1936 and 1937 was among the highest on record. Accordingly, the interval was a short one, namely 9 years, the briefest observed in a century, thus rendering the double cycle but 20 years, as compared with 24 years from 1893 to 1917, and 23 from 1870 to 1893. However, when the interval is taken in the astronomical fashion from minimum to minimum, its length is 22 years from 1856 to 1878, 23 to 1901, and 22 to 1923.

The regular coincidence of drought with sunspot minima but only with sunspot maxima of high numbers appears to furnish the explanation for its general prevalence over the West for the past

decade. The drought about the minimum of 1933-1934 carried over to meet the oncoming effects of the maximum, which began in 1936, to continue generally through 1937. Though the rainfall totals for 1938 were good as a rule, the distribution was of the poorest, much of the West being dry from April to September, a period that coincided with an average of 122 spots for the five months concerned. A similar agreement of sunspots and faulty distribution has occurred in 1939, the average for the first three months being 75 spots, by contrast with 115 spots for April and May.

Nature and origin of aspen parkland. The broad ecotone from the prairie to the boreal forest of Canada is marked by groves of aspen that increase in size and extent to the north, where they merge with the spruces. In view of the effect of fire upon forest, it has been a natural assumption that parkland is the rear guard of a retreating climax. This is not only contrary to the opinion of settlers, who believe the aspens to be advancing, but is likewise refuted by the general behavior of deciduous woodland when burned in contact with grasses. Since the great majority of hardwoods are able to form root sprouts after fire or cutting, such stands may be reduced to scrub, but are rarely if ever eliminated, even by annual burning. In fact, the regular effect of fire is to favor shrubs and trees at the expense of grass, with the consequence that not only do the aspen groves increase in size, but new ones also develop along the border. Extension is likewise brought about by grazing and to some degree by cultivation, which tends to restrict itself to the prairie.

The term parkland has the advantage of being indigenous, but is not strictly accurate ecologically, since the aspens form dense copses or motts, instead of being scattered in true parks or savanna. It is probable that two processes con-

tributed to the original formation of parkland, which is postclimax to the prairie. The first was the lagging of the aspens as the boreal forest straggled northward after a climatic shift to the warm-dry phase, and the second the effect of grass fires along the front, which took a heavy toll of the conifers. Today the groves comprise a tall central mass encircled by two or three zones of fire saplings, while fire scars are frequent on the trees. Rodents have been supposed to play a part in the spread of seedlings from the parent groves, but their contribution is quite insignificant.

Such an analysis of aspen parkland brings this disclimax into harmony with all the others that have encroached upon the prairies. These are oak-hickory woodland on the east, mesquite and desert scrub in the southwest, chaparral along the mountain fronts, and sagebrush in the Great Basin. Migration by climatic compulsion has carried trees and shrubs into the grassland, and the laggards at the next turn of the cycle have supplied the relicts upon which man has operated through fire, grazing, and cultivation.

Relationship of Palouse and mixed prairie. While the term Palouse refers to a particular region of the Northwest, its use is justified for the more extensive climax association, in which the striking bunch grasses, *Agropyrum spicatum* and its variety *inermis*, are the characteristic dominants. It seems probable that the derivation of these from the widespread *A. smithii* was caused by a shift toward winter precipitation, which set apart the climate and climax of the Palouse region. This appears to have been a relatively recent event, since practically all the other dominants are those of the mixed prairie and the transition between the two is unusually broad. This is due in large measure to the basin-and-range topography, in which dovetailing on the

two levels is a typical phenomenon. In consequence, it becomes necessary to recognize two divisions or faciatiions, namely, the Palouse prairie proper of southeastern Washington and adjacent Idaho and Oregon, and the outlying transition, in which the dominants of the mixed prairie assume a rank equal to that of *Agropyrum spicatum*. This extends from northern California and Nevada through all of nonforested Idaho and for some distance into Montana and Utah. A similar shift occurs along the southern boundary of British Columbia, but the details of this are still to be worked out.

In general, the divisions or associations of the grassland climax correspond to rainfall differences, while the subdivisions or faciatiions are chiefly the outcome of temperature contrasts. As a result, faciatiions may assume both an altitudinal and a latitudinal expression; for example, the submontane type of mixed prairie in the central Great Plains has its counterpart at moderate levels in central Alberta and Saskatchewan. It is significant that the dominant grasses which mark this cooler faciatiion should all be of the circumpolar type, namely, *Agropyrum pauciflorum*, *Koeleria cristata*, *Festuca ovina*, and *F. scabrella*. Meanwhile, such typical southern species as *Bouteloua gracilis* and *Buchloe dactyloides* have disappeared, the latter below the international boundary, while grama may survive as a relict much farther north.

Types and rôles of short grasses. In the further analysis of life forms as indicators of factors and processes, it has become clear that the term short grass covers a number of subforms, quite apart from the well-known sod and bunch types. The best known and most typical are species of *Bouteloua* and *Aristida*, together with *Buchloe* and *Hilaria cenchroides*. These are southwestern in ori-

gin and their low stature denotes the impress of a subtropical climate. They have moved northward into the mixed prairie during dry phases that simulate their original climate and have persisted as an open under story to produce the well-known short-grass plains during the grazing period. A second type, the short sedges, have accompanied the boreal grasses in their migration from circumpolar regions. The two more important are *Carex filifolia* and *stenophylla*, found in the Palouse as well as the mixed prairie, where their ranges overlap those of the gramas. In spite of their northern origin, they are more xeric than grama and buffalo grass, and they persist westward to characterize the driest faciatiion of the mixed prairie. When the associated mid-grasses are grazed off, these sedges form a short-grass disclimax, similar to that of the Great Plains, in which they may also occur.

Much as *Carex* replaces *Bouteloua* in the drier districts, so the small forms of the boreal *Poa*, such as *scabrella*, *secunda*, and *arida*, play a similar rôle in the cooler north, where grama is less abundant or absent. However, these are more delicate plants with poorer root systems, after the fashion of annuals, and are more easily replaced by the mid-grasses when these are released from heavy grazing pressure. The fourth type comprises true annuals, of which *Bromus tectorum* is the best example. Under severe grazing, its reduced stature, high seed production, and early development make it the ultimate winner wherever it obtains a foothold. In the past quarter-century it has swept across the Palouse into the Great Plains, where it can only be checked by fostering and replacing the native perennials.

The sagebrush disclimax. As disturbance communities produced by man, the various disclimaxes indicate not only the course of deterioration, but also the

processes necessary to rehabilitation. This is perhaps best exemplified by sagebrush, the vast extent of which lends color to the plausible assumption that it forms a climax. The several types of evidence were invoked two decades ago to confirm the hypothesis that *Artemisia tridentata* had advanced from the Southwest in a dry phase and retreated during a moist one, to leave an open savanna over the major portion of the Great Basin. This view was supported by relict patches of Palouse or mixed prairie wherever protection against grazing occurred, by numerous observations through the climatic cycle of the effects of grazing and of fire, and by the testimony of early explorers and ranchers. These were supplemented by preliminary experiments, which demonstrated that overgrazing depleted the grass and increased the sagebrush, while protection or removal by fire, grubbing, or dragging again gave the grasses the upper hand in the competition.

In the past few years, this testimony has been greatly reinforced by demonstrations carried on by the Forest Service and the Soil Conservation Service, as well as through increased burning by the stockmen themselves. Such results are now so numerous and extensive as to leave no doubt that over most of its area sagebrush is not a climax at all, but a consequence of disturbance. Since it rarely forms root sprouts, sagebrush may

be almost completely eliminated by fire, the climax grasses reappearing in normal condition after two to three years and persisting as long as grazing is regulated. Some seeds survive all but the severest fires and thus may serve to maintain an open savanna such as existed before the grazing period.

Though it seems paradoxical, the reduction of the grass and the development of a disclimax renders the dominant species of the latter relatively more valuable than before. This is especially true of sagebrush because of its value for winter browse, and as an insurance against drought and the drifting of snow cover. Hence, the present tests by means of experimental grids are based upon the desirability of leaving unburned strips to secure these values. Since sagebrush has but moderate usefulness for erosion control, the grids are also designed to determine the need of reinforcing it with contour trenches. The question of the proper balance between climax and disclimax species constitutes one of the most important problems in conservation and must be taken into account in all field demonstrations and experiments. Theoretically, when it is a choice between climax and disclimax, the former will regularly give the highest sum of values, but as just suggested some combination of the two may yield a wider range of values, as well as require less effort for its maintenance.

PALEOBOTANY

RALPH W. CHANEY

Preliminary investigation of a Miocene flora from Shantung, China has been described in the report for 1938. A systematic study of this flora has now been published, and the discussion of its age and environmental significance is nearing completion. An incidental survey of the Tertiary distribution of vege-

tation in Eurasia and North America has made possible the following general conclusions:

1. In all the northern continents, the distribution of forests during Eocene and Miocene time shows latitudinal zoning. The zones, which may be roughly classified as subtropical and temperate, have

an east-west trend, and their latitude in Eurasia is approximately the same as in North America. Since corresponding floral units of today have a similar relation to latitude, we may conclude that as far back as the Eocene epoch, the North Pole has maintained essentially its present position with relation to the northern continents.

2. In both Eurasia and North America, Tertiary floral units range farther north on the windward than on the leeward coasts. Modern vegetation shows a similar northwest-southeast trend across these continents, roughly parallel to the isotherms of middle and high latitudes. This departure from coincidence with parallels of latitude is believed to be due to the effects of ocean currents on the western sides of the continents, and to increasing continentality toward the east. Assuming a similar relation between isotherms and floras of homogeneous climatic types (isoflors) during the Tertiary period, we may conclude that the distribution of ocean basins and continental platforms has been essentially unchanged since the Eocene epoch. Such a conclusion is at variance with theories of continental drift which place the date of movement of the northern continents to their present position as late as the Pleistocene epoch.

Investigations of colleagues and students which bear upon the problems of Tertiary floral history may be summarized as follows:

D. I. AXELROD. Study of the Tehachapi flora from the western border of the Mohave Desert reveals the invasion of southeastern California by an arid, north Mexican element during the Miocene. The flora includes the ancestors of many modern California endemics. Extensive collections of Pliocene plants have been made over a wide area in the Great Basin; preliminary study indicates that a mesic forest at the north was gradually replaced southward by xeric vegetation,

as is the case today. This suggests that the major topographic features were already developed there by late Tertiary time.

C. CONDIT. The vegetation of late Tertiary time in what is now the foothills of the Sierra Nevada included many plants which have survived with little change in this region. Uplift in comparatively late geologic time has brought a more humid climate to the region in Nevada County from which the Oakvale Mine flora has been collected. As a result, the more xeric species of this flora have been eliminated from central California, and are now confined to arid areas in Mexico and China. A well-preserved flora from Tuolumne County contains, in addition to a modern Californian and a Southwestern element, the remains of plants now restricted to the eastern United States. Changes in topography and rainfall in later Tertiary time appear to be responsible for the altered distribution of the living descendants of such plants.

E. DORF. Study of the ancestry of Tertiary trees has been continued in the Cretaceous of the Rocky Mountain region. A report on the flora of the Lance formation is now being prepared for publication, based on new and old collections, and on extensive field work. A more accurate placing of the Cretaceous-Tertiary boundary has been made possible on the basis of the re-study of this critical area.

H. D. MACGINITIE. Continued investigation of the Chalk Bluffs (Auriferous Gravels) flora of California has led to the conclusion that it represents the vegetation of the Middle Eocene. Relationship with certain of the older floras from Yellowstone Park and the Green River Basin has been noted. Forests made up of similar trees may be found living on the east front of the Sierra Madre, in Vera Cruz, Mexico, under climatic conditions warmer and more humid than those at Chalk Bluffs today.

DIVISION OF ANIMAL BIOLOGY

GEORGE L. STREETER, CHAIRMAN

Though approached in diverse ways, there is an underlying goal toward which the researches of the Division of Animal Biology are in large part directed, namely, the understanding of man's structure as the basis of his behavior. This includes a knowledge of how a new individual is formed and how characteristics are inherited by offspring from their parents, how the component parts operate when once established, and the factors that determine the structural and functional characteristics of these parts throughout development, maturity, and old age. Because of the comprehensive nature of the goal the approaches are being made by various groups of investigators, each group being proficient in the specialized techniques necessary for its particular approach. Within the Division there are four such groups or departments, geographically separated but allied in common endeavor. Provision has been made for frequent conferences between them and, where advantageous, cooperative researches are being engaged in, as will be seen in the body of this report.

In the Department of Embryology the increased amount and improved preparation of our primate material have in the past few years yielded new insights into the early phenomena of development. It is found that embryos are not alone engaged in growth and development, but they are also engaged in the meantime in maintaining themselves, that is, the embryo not only develops but also exists. At each developmental stage the structure of the embryo is so designed that it can function as a self-sustaining organism. With each developmental advance there is an adaptive alteration in

its organization, ensuring at all times the adequate performance of its physiological functions. To meet these changing requirements for existence there are developed a series of temporary devices, and when the particular requirement is no longer there the device is altered or permanently discarded. We thus find in embryos a series of ephemeral structures which heretofore had largely been regarded as phylogenetic vestiges but now are proving to be essential though temporary organs. Our experience is thus teaching us that if our embryonic specimens are properly prepared there is much that can be learned regarding their early functional activities. This, in turn, reveals the significance of structures whose purpose had been heretofore obscure. When we now look at our sections under the microscope we ask ourselves which of the objects before us are expressions of developmental changes and which are structures serving to meet the immediate physiological demands of the embryo concerned. An untrodden way is opening before us.

During the past year a major event has been the acquisition of two "earliest" human embryos in a condition that permitted ideal photographic records and preparation for microscopical study. In addition to the Miller specimen, one can now study in this laboratory the three youngest known representatives of early human development. The importance of this material can scarcely be overestimated. Almost of equal importance is the early chimpanzee embryo obtained through cooperation with Professor Yerkes' laboratory at Orange Park, Florida. In the report of the Department a variety of embryological studies will

be described, including cytological and chromosome investigations with bearings on genetics. Considerable work has been done on the physiology of reproduction and the endocrine organs concerned. Biochemical studies have been made of the secretory mechanisms during the fetal period, and as in past years attention has been directed to the help that can be had from comparative anatomy.

In the Department of Genetics inheritance in plants and animals has been studied as it occurs both in nature and under the conditions of experimental interference. Studies have been made of specific regions of a selected salivary gland chromosome in fruit flies, where changes are induced by radiation of the sperm by X-ray or ultraviolet light. The changes induced are in the nature of inversions, deficiencies, and differences in band intensities. Among the results of these studies is the evidence that the activity of a gene is in part dependent on its immediate environment. The activity of a particular gene may be changed or suppressed by relocation and by being brought in contact with a foreign section of the chromosome. The various regions of a chromosome differ in the effect they produce. It is further found that when breaks in a chromosome are induced experimentally they are more numerous in certain regions. These observations show that chromosomes have a definite structural design or composition. Other types of abnormal development have been obtained by crossing certain wild types of fruit flies, and it is concluded that the resultant sterility of such hybrids is to be attributed to a maternal effect of the hybrid chromosomes on the egg cytoplasm prior to fertilization.

Active work has been continued on the effect of colchicine on the chromosome mechanism in plants. It is found that the action of colchicine is not confined to doubling the number of chromo-

somes, but it also induces the elimination of individual chromosomes and produces new unbalanced chromosomal types. In such material it is possible to trace the embryonic layers, and it is found that they do not remain confined to their primary layer with the aloofness that had been attributed to them. The "dermatogen," for instance, not only gives rise to the epidermis but also contributes in considerable measure to the internal tissues of the leaf and floral parts. These chromosome studies are providing an improved basis for the understanding of the mechanism of heredity and development.

In addition to the attention given to chromosomes, active study has been continued on other factors that control development and growth, notably the activity of the hormones contained in the secretions of the anterior lobe of the pituitary gland. Improvements have been made in the assay of these substances and a more complete separation of the different hormones has been attained. New knowledge has been gained of their interaction with other hormones and their modification by the use of chemical agents. An entirely different aspect of growth is represented by the group working on mouse leukemia. In determining the nature of the resistance of the body to uncontrolled proliferation of leukemic cells, these investigators are adding to our understanding of tumors in general. During the past year it has been found that resistance to certain transplanted leukemic cells can be induced by means of leukemic tissue, killed by heat. That is, the action of living cells is not necessary for the induction of body resistance, a conclusion which is contrary to the view heretofore generally held. In connection with these investigations in mouse leukemia it was found that leukemic-like cells could be induced by treatment of the animal with trypan blue. This is not a true leukemia,

however, for it lacks the physiological characteristics of a progressive malignant growth.

The later consequences of heredity and growth processes are covered in studies of the physical characteristics of three selected ethnic groups: American Indians, Negroes, and whites. Attention is also called to the survey of the human resources of Connecticut, which was carried out as a joint research with the State of Connecticut. It becomes clear from such studies that the character of the population of any country has biological implications which are subject to investigation by current methods of genetic analysis.

The research activities of the Nutrition Laboratory have in the past centered largely around the factors governing heat regulation and heat production in animals and humans. This has also been true for the period covered by this report. The heat production while the body is at complete rest with respect to muscular activity and food intake is known as the individual's basal metabolism, a subject to which the Nutrition Laboratory has made large contributions. The data that have been gained have already proved of great clinical value in the recognition of diseased states; there remain, however, many factors bearing on it that require further investigation. For instance, it has been found that animal species having the same weight and surface area may differ one from another in their heat-producing powers. Thus the basal heat production per unit of surface area is not constant among all warm-blooded animals. This discovery makes it necessary to determine to what extent these differences are based either upon a purely physical loss of heat or, as is more probable, upon differences in the chemical composition of the body tissues. This calls for further study of the oxygen-carrying power of the blood and for a more detailed study

of the physiology of its circulation and distribution. There is much to be learned regarding the part played by vasomotor activities and likewise about the whole subject of muscle tonus.

Another instance of the unexpected that now demands attention in this field of research is the study of the consumption of simple sugars and their effect on heat production. The work has progressed far enough to reveal that the actual heat production as measured directly with the calorimeter is not equivalent to the heat production calculated from the absorption of oxygen, that is, the respiratory exchange. It seems probable that in such experiments the combustion of body material is not completed at the moment of measurement, and it follows that this possibility must be reckoned with in making comparisons between direct and indirect heat measurements. To understand heat production one must consider both that which originates from food immediately burned and that which originates subsequently from food that is changed into body substances through intermediary processes. The rate at which these poorly understood changes occur is involved in the knowledge of how food is used in the body.

Among the other researches at the Nutrition Laboratory, attention is called to the observations on heat production in the rabbit under various experimental conditions. Because of the wide use of the rabbit in biological investigations and because of its wide range in adult weight and size, the data that have been obtained assume considerable practical importance. Among other studies that have been made during the past year will be found: the analysis of foods commonly eaten by the Navajo Indians; experimental observations on the chick embryo, throwing light on the earliest activities of the nervous system; and observations

on the respiratory exchange in diabetic patients.

Whereas in the other departments of the Division there is much overlapping and integration in the various investigations, this is less true of the Tortugas Laboratory. The reason for the maintenance of that Laboratory and the nature of the studies carried on there rests on the great variety and abundance of marine life that it provides in easily available supply. A coral island far enough out from mainland to be free of contamination provides a pure sea-water environment which each year is eagerly taken advantage of by visiting investigators whose studies require such facilities. During the summer of 1939 the Laboratory was in operation from June 1 to August 8 and was utilized by twelve investigators and two research assistants. Though the working season at Tortugas is limited to a period of not much over ten weeks, it is to be remembered that the visiting investigators carry back to

their home laboratories specimens and data that usually require a considerable time for their analysis and preparation for publication.

The work this year included: studies on the Tortugas ciliates and parasitic protozoa; further investigations on the swarming of the Atlantic palolo worm; diatoms and their reproduction; color changes in fish embryos; embryology of the nurse shark; various studies on the effect of light on biological processes, including the photodynamic effect of vital dyes; regeneration in starfish and ciliates; protoplasmic electrical phenomena in *Valonia* under varying conditions of the surrounding medium; enzymes in *Valonia*; ecology of the amphioxus; distribution of amylase in amphioxus; parasites in fish blood; and also serological studies of fish blood. In the following pages a description is given of these various studies along with those of the other laboratories of the Division.

DEPARTMENT OF EMBRYOLOGY

GEORGE L. STREETER, DIRECTOR

EMBRYOLOGY

EARLY ANTHROPOID AND HUMAN EMBRYOS

The years 1938 and 1939 were eventful ones in this laboratory. They brought us specimens which revealed the character of the early ovum and the manner of its implantation in the chimpanzee, this being the first time such data have been available for any of the great anthropoid apes. Along with that major acquisition we have also obtained two human ova of a very early period of development and preserved in a manner that permitted complete photographic records and ideal histological technique in their preparation for microscopic study. These new human specimens together with the Miller ovum constitute a normal group of the earliest known stage of human development, a stage preceding the appearance of the yolk-sac and the differentiation of villi. They replace the diagrammatic concept of this period of development, which up to the present time had been almost entirely hypothetical, and whose inaccuracies had led to confusion in the understanding of the initial organization of the embryo.

The early ova of the chimpanzee were obtained through cooperation with the Yale Laboratory at Orange Park, Florida. One of the two specimens is a pathological ovum just in the process of making its way through the uterine epithelium. The other is a normal specimen, of a stage a little younger than any known human specimen, and has an estimated age of $10\frac{1}{2}$ days. It portrays the ovum just after it has penetrated the maternal epithelium, the point of entry being still open. The success in this

carefully planned project is due, on the part of the Yale Laboratory, to Dr. Yerkes and Dr. Elder, and on the part of our laboratory, to Dr. Hartman and Dr. Heuser. The significance of the observations made in connection with this material, and of the material itself in its histological perfection, is far reaching because it constitutes our first view of the phenomenon of the mechanism of implantation in the great apes and because of the light it throws on human implantation, with which that in the chimpanzee possesses a close affinity. If there is any real gap between the macaque material, which we now have in such abundance, and the less well understood human implantation, this chimpanzee material will assist in bridging it. In the macaque the invasion of the maternal tissue is superficial and only sufficient to accommodate a partial submergence of the ovum; whereas in the human the whole ovum sinks beneath the uterine surface, with the epithelium healing over the denuded surface. The chimpanzee is like the human in this respect, and it also approximates the human in the precocity of the primitive coelomic reticulum (mesoblast). A preliminary account of the "Yerkes A" ovum has already been published, but a more complete account is now in course of preparation by Dr. Heuser, and will include observations on the second chimpanzee ovum, which we regard as abnormal.

Regarding the two new human ova, which were secured through the cooperation of Dr. A. T. Hertig and Dr. J. C. Rock, only a brief note will be made at this time. They were obtained surgically

on the 11th day, and after careful study of their gross relations they were cut in a chosen plane of section in faultless series. A preliminary examination with the microscope reveals that the two ova correspond closely to each other in size and character, and to the Miller ovum, giving assurance that all three are normal. This means that we now for the first time have a sure point of departure for analysis of the subsequent events in the organization of the ovum and its further development into embryonic and extraembryonic or auxiliary structures. With the kind of evidence which such specimens place at our disposal, we shall no longer be willing to tolerate the poor histological material and the wild speculations that have so largely dominated our past interpretations of the early stages of the human ovum. We have arrived at a day of better embryological quality. The specialist is replacing the amateur in all steps of the work. It now remains for us to provide a complete account of this important material and in a form that will make it conveniently available to embryologists in general. Such an account is now in course of preparation by Dr. Hertig.

NEW RECONSTRUCTION OF THE MILLER OVUM

The two new human ova obtained through Dr. Hertig and Dr. Rock made it necessary to re-study the Miller ovum, which is of about the same stage of development. By replotting its five available sections in the form of a profile reconstruction, the Miller ovum can be brought into complete conformity with the more complete Hertig specimens. Both in size and in detailed form they approach one another closely, and all three are unquestionably normal. We now know that the human ovum is much like that of the macaque in its develop-

ment, differing principally in its more precocious and more abundant primitive fibroblastic reticulum, the so-called primitive or extraembryonic mesoblast. It is concluded that in none of these ova has the yolk-sac yet appeared. What was first regarded as possibly a yolk-sac mass in the Miller ovum is now shown to be a part of the combined primordium of the primitive mesoblast and gut endoderm (fig. 1), and with attention being called to it by the new specimens one can recognize in the Miller specimen a small exocoelomic cavity closed in by a mesothelial membrane, known in this laboratory as the Heuser membrane.

STUDIES OF EARLY STAGES IN THE MACAQUE EMBRYO

The mesothelial membrane enclosing the exocoelomic space in early macaque ova, to which our attention was first called by Dr. C. H. Heuser, has recently been studied by him in its entirety. He has traced the origin of its first cells from the cell group underlying the germ disc. He then shows how they form a membrane that becomes continuous laterally with similar membranes formed from cells delaminated in situ from the trophoblast on all sides. In this way there is formed a thin-walled closed cavity or vesicle which occupies a large portion of the chorionic cavity. The functional significance of this space and the membrane enclosing it has not yet been determined. However, they appear to be characteristic for primates, and that their utility is of short duration is made apparent by the fact that the membrane remains intact only from the 12th to the 20th day, which is when the chorionic villi become definitely formed. At that time there occurs an increase in the extraembryonic mesoblast in the space between the exocoelomic membrane and the trophoblastic wall. This increase of mesoblast is partly at the expense of the

former. As the membrane disintegrates the mesoblast takes the form of a fibrous reticulum whose strands extend from the chorionic wall to the surface of the yolk-sac and the amnion, and through whose meshes fluids can freely pass. It is these persisting delicate strands that are known as "magma reticulare" in human specimens.

A study of the macaque egg as it exists free in the uterine cavity during the two

therewith grow larger, but they also fulfill the requirements of living organisms. In order that embryos may maintain themselves at their respective biological levels, it is necessary that their structure be so designed for each developmental stage as to ensure an adequate physiological performance. It follows that their design should enable them to continue living indefinitely at any respective stage so long as no

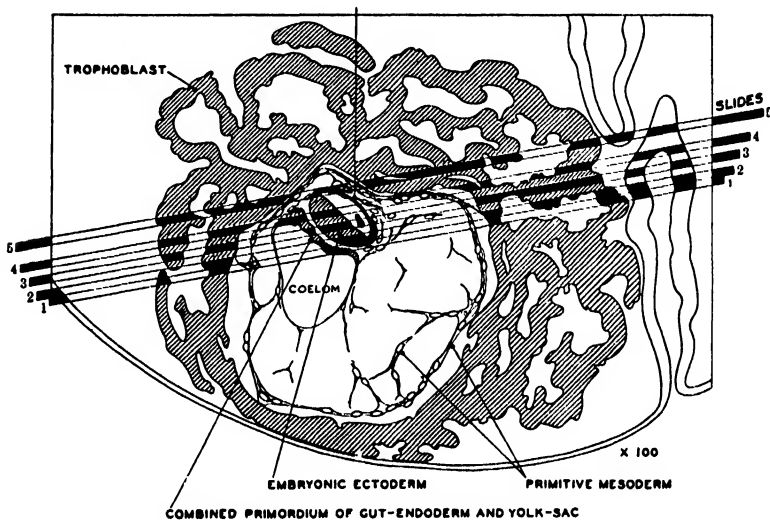


FIG. 1. There are only five sections through the implantation area of the Miller ovum. The remainder had to be supplied by deduction and interpretation. A profile reconstruction of that character was made and published in 1926. Since two new normal human embryos of about this age are now available, it has been possible to improve on the original interpretations of the Miller specimen, and the latter is thus brought into close conformity with the two Hertig ova, as this schematic sketch reveals. The presence of an exocoelomic membrane (Heuser's membrane) had been overlooked, and what was thought to be a possible yolk-sac is now interpreted as a layer of multiplying cells which antecedes both gut endoderm and yolk-sac.

days preceding implantation has been made by the writer. It was found that already in the blastocyst stage one can recognize ephemeral structures which are concerned with the immediate physiological requirements of the egg rather than being stages in the building of future organs. Embryos, in fact, are engaged in two quite different activities. They not only develop from the simpler forms into more complicated ones and

change in themselves or their environment renders that design inadequate. In short, the embryo not only develops but also exists. To a large extent it is possible to discern the respective cell groups engaged in these two functions. In tracing the maintenance group it is seen that as the requirements for existence progressively change there are developed a series of temporary devices with which those particular needs are met. When a

particular requirement is no longer present, the respective device is altered or permanently discarded. What have been termed vestigial structures appear in many cases to fall in this series of evanescent organs. It is suggested that the thin trophoblastic wall of the free blastocyst is such an organ. It constitutes a functional membrane adapted to the concurrent needs of the young organism. It is to be distinguished from the undifferentiated remainder of the blastocyst wall, which is interset at the embryonic pole. This pole consists of the embryo-forming cells and, overlying them, certain auxiliary cells which will form the attachment mechanism and various extraembryonic membranes. At this place it may be pointed out that with better material and improved histological techniques, it is becoming possible to observe in greater detail the functional activities of the structural elements that constitute the egg and early embryo. To have this information in the primates is of utmost importance.

FUNCTIONAL MATURATION OF SKELETAL MUSCLE

Using living rat embryos, Dr. W. L. Straus, Jr., has studied the developmental changes that occur in skeletal muscle at the time of its first visible contraction. He found that on the 16th day of gestation electrical stimulation through the skin induced visible contractions of the arm musculature. On the 15th day stimulation gave no visible response. The point therefore was to learn how the fibers of the 16th day differed from those of the 15th. In general they proved to be larger, and the better-developed ones contained more myofibrils. These differences, however, are regarded by Dr. Straus as insufficient to account for the marked difference in their response to stimulation. He concludes that there must be important supplementary extramuscular factors,

and suggests as possibilities the more advanced organization of the connective tissue and the greater degree of articular cavitation which characterize the 16-day specimens. He also finds that muscular contraction can be produced by direct stimulation of the nerves on the 16th day, though the nerve endings at this time are epilemmal and of relatively immature form. These studies of Dr. Straus are still in progress but are sufficiently advanced to warrant this preliminary report.

DEVELOPMENT OF THE ADRENAL CORTEX OF THE ALLIGATOR

To provide a better structural basis for his endocrine studies in the reptile, Dr. T. R. Forbes has studied the embryology of the adrenal gland in the alligator, and especially the adrenal cortex. He traces the cortex from a primordium of coelomic epithelium which spreads laterally to merge with the germinal epithelium of the sex gland and which can be distinguished from the latter only by the absence of germ cells. The primordia of both organs thicken in a similar way and project cellular cords into the underlying mesenchyme, and the adrenal throughout development retains its contact with the sex gland. The cortical cords rapidly penetrate between the mesonephric glomeruli and the aorta. Branching and becoming tortuous, they become detached from their seat of origin, the coelomic epithelium. Before hatching, the adrenal chromaffin medullary tissue migrates forward to form basophilic islets in among the cortical cords. In the adrenal of the alligator, Dr. Forbes finds, the cortical and medullary tissues are never segregated into discrete peripheral and central zones.

OVUM OF THE MINK

Dr. R. K. Enders of Swarthmore College, who has been aiding in a cooperative study of the physiology of repro-

duction in mink, has obtained and studied in the living condition three tubal ova. They were estimated by him to be about 16 hours after fertilization. They were free of follicle cells, the vitellus had shrunk, and sperm heads were observed in each of them. The zona pellucida and general appearance of the ova are typically mammalian. The vitellus is very dark and opaque throughout, owing to the refractive properties of the

globules of lipid material contained in the cytoplasm. This is a characteristic common to carnivores. When focused properly, the peripheral granules can be measured and are 3 micra in diameter. The total diameter of the ova varied individually between 135 and 150 micra. The vitellus itself varied from 103 to 110 micra. These eggs are therefore larger than the mouse egg and about the size of that of the macaque.

CYTOLOGY

RÔLE OF PLASMAGEL IN CELL ACTIVITY

The part played by alternate surface gelation and solation in the movement of blood cells was first suggested by Dr. W. H. Lewis, as referred to in Year Book No. 31 (1931-1932). Since then further studies have been made by him of this phenomenon in other cells and in connection with other activities. The motion picture technique makes it possible to record slow changes of this character, and when the films are projected the changes which in nature are slow and gradual can be shown with sufficient acceleration to make them evident. This technique has been steadily improved and used extensively by Dr. Lewis in his studies of cell activities. He finds that changes in viscosity of protoplasm, from gel to sol, from sol to gel, and the intermediate states, involve important functions of the cell. When the probability was recognized that active cells possess a superficial layer of gelated cytoplasm, the plasmagel layer, which exerts contractile tension on the rest of the cell, the way was opened for the explanation of a number of cell phenomena which before had been obscure.

It is pointed out by Dr. Lewis that a tension uniformly distributed over the surface tends to make the cell spherical and that local variations of it produce distortions and cell processes. It is the latter that provide locomotion. On the

other hand, when a cell is about to divide it retracts its processes and pseudopodia, and this is done by increasing the viscosity of the superficial plasmagel layer covering these processes, and restoring a uniform tension over the whole cell. The cleavage of cells in mitosis is found by Dr. Lewis to result from the formation during anaphase of a dense equatorial band of the plasmagel layer analogous to the constriction ring of the migrating lymphocyte. By its increased contractile tension this annular band compresses and then constricts the cell, all of which can be followed in the motion picture record owing to the refractive change in the superficial plasmagel layer.

It is also probable that, deeper within the cell, changes in viscosity of its protoplasm are of functional significance. For instance, the oscillation of individual chromosomes in the paths of the poles of the spindle indicates that invisible fibers must connect these with the poles and that it is the gelation of these fibers that causes the contractile tension on the chromosomes. It is interesting to note that the two fibers of each chromosome undergo alternate changes in viscosity and that the chromosome thus oscillates first toward one and then toward the other pole of the spindle. When the chromosomes are pulled or split apart, the oscillation ceases and each half is

drawn toward its respective pole by the contraction of its spindle fiber.

In cultures of malignant tumors, abnormal cell division is occasionally seen, in which the cells show marked distortions and lobulations during mitosis and afterward in the young daughter cells. These distorted forms can now be explained by the presence of irregular and shifting contraction bands of the plasmagel layer.

VISIBLE ORGANIZATION OF THE CHROMOSOME

In collaboration with Dr. D. F. Poulson, Dr. Metz during the past year has completed an account of their studies on the structure of the nucleolus-forming regions in the salivary gland chromosomes of Diptera. The fact that nucleoli are associated with specific regions of specific chromosomes lends importance to the structure of these regions, the supposed nucleolus organizers. Aside from their bearing on the nucleolus problem, the relation of the nucleolar regions to the banded structure of the salivary chromosomes is of importance for any light it may throw on the ultimate organization of those chromosomes. One of the ways in which these regions differ from the remainder of the chromosome is a difference in staining property, and they are therefore spoken of as heterochromatic regions. Even in this property the distinction is not a clear one, for it is found, on comparing different regions and conditions in giant salivary chromosomes, that heterochromatin and other chromatin intergrade through a series of intermediate conditions.

The material studied was from two different genera of Diptera, *Chironomus* and *Sciara*. In *Chironomus* two nucleoli were found associated with chromosome IV and could be demonstrated in both living and fixed specimens. In the nucleolar regions the banded structure is

definitely modified. In the region of the larger nucleolus the chromatin breaks up into a heavy network in which solid discs are replaced by interconnected chromatic spheres and granules, and this structure fades out into the clear nucleolar substance, where achromatic materials preponderate. In the smaller nucleolus the banded structure is less disturbed, though a chromatic network runs out from the bands into the clear nucleolar substance.

In *Sciara* the salivary chromosomes exhibit the phenomenon of "puffing," that is, there are regions which are normally banded but at times are found to be puffed. This condition was described in the report of last year. It is now certain that "puffing" is not an artifact and that it is not influenced by the fixation and staining methods employed. It is cyclic; when it occurs, it is seen simultaneously in all the nuclei of the gland and in equal degree. It is concluded that this phenomenon is dependent upon physiological and external factors rather than upon genetic constitution. These puffed areas in *Sciara* resemble closely the two nucleolar structures in *Chironomus*, differing mainly in that in *Sciara* the banded structure appears to be modified directly to form the nucleolus-like regions, whereas in *Chironomus* the chromatic bands are preserved but blend with the less chromatic material of the nucleoli.

Dr. Metz has continued his observations on the finer chromatic structure of the chromosome by means of new material and by improved photographic records of crucial specimens. He has added supporting evidence to his previous interpretation that the organization of the giant salivary chromosome is that of an alveolar or honeycomb system superimposed on the pattern of transverse discs. The evidence for existence of chromonemata, which has been so stoutly maintained, he explains as ap-

pearances resulting from distorted chromosomes. Similar pictures of distorted cytoplasm can be artificially reproduced by manipulation of the chromosomes. The optical pattern resulting from the alveolar organization gives latticework or threadlike lines, especially in distorted chromosomes. But that these cannot be interpreted as the much desired chromonemata he concludes for the following reasons: first, in side view they typically form a diagonal crisscross pattern at all optical levels; second, the lines regularly intersect at the granules; third, the lines frequently continue diagonally across both chromosomes of the pair; fourth, the lines are less numerous than would be required if they actually represented chromonemata; and fifth, they differ widely in number in different parts of a chromosome. Dr. Metz continues his destructive evidence into the domain of the "chromomeres," which he holds cannot be biological units. Some of them, he points out, are heavy-walled droplets made from material from separate discs, one of which may be removed by a deficiency; others are granules of chromatin, also similarly compound, and they may lie between the "chromonemata." Apparently the time is ripe for an entirely new interpretation of the significance of the chromatic system of the chromosome, and it can be based on better material than the salivarian pioneers had at their disposal.

STRUCTURE AND PROPERTIES OF LIVING CHROMOSOMES

The perfection of a method for studying chromosomes of the salivary gland in the living state has made it possible for Dr. J. B. Buck and Dr. R. D. Boche to demonstrate that in the normal living condition there is very little free fluid and the chromosomes fill or nearly fill the nucleus, the nuclear volume thus essentially being the same as the chromosome

volume. In addition to the chromosomes there are also the nucleolus and chromocenter when these are present. The study covered the salivary gland chromosomes in four genera of Diptera. The technique consists in flattening living larvae between slide and cover glass in a manner that renders the salivary nuclei and chromosomes available for measurement and observation under high magnification directly through the body wall and in an unquestionably living state.

By asphyxiation of *Sciara* larvae in a micro gas chamber, where they can be subjected to pure CO₂ or N₂ gas, it was found possible to shrink the salivary gland chromosomes into a spherical clump whose diameter gave an accurate measure of its decrease in volume. Under this condition the nuclear volume remained constant, showing that in the exchange of fluid none was lost from the nuclei and that the phenomenon is an intranuclear one. Shrinkage of the chromosome mass was found to be reversible up to a maximum of about 65 per cent loss in volume. Injection of hypotonic and hypertonic saline solutions into the larval body cavity causes reversible swelling (at least 20 per cent) and shrinking (at least 35 per cent) respectively of both nuclei and chromosomes. As a guide for distinguishing between living and dead chromosomes these investigators followed an analogy borrowed from protein chemistry. As long as the chromosomes were able to take in and give out fluid they were regarded as comparable to native proteins. The loss of this capacity, like the irreversible loss of solubility following protein denaturation, was accepted as an index of death of the organism.

In living preparations of the kind just described Dr. J. B. Buck reports the following observations on the visible structure of the chromosomes: the banding in *Sciara* and *Drosophila* is sparse and indistinct, in contrast with

Simulium and *Chironomus*, where it is about as sharp and detailed as in fixed preparations; in all four genera studied most of the bands are smooth or finely granular and homogeneous, with few or no vesicular bands seen; in optical cross section, the chromosomes are round with a dark margin and a uniformly granular interior; no longitudinal fibrillae, such as appear as "chromonemata" in acetocarmine preparations, are visible; and finally, no pronounced form or alveolar structure of the achromatic regions was seen.

HYDROGEN-ION CONCENTRATION OF INSECT BLOOD

In connection with their physico-chemical studies of living chromosomes, Dr. R. D. Boche and Dr. J. B. Buck have found it necessary to know in detail the nature of larval blood. This they have determined for *Drosophila*, *Sciara*, and *Chironomus*, checking their determinations in each case by different indicators, including colorimetric indicators, microquinhydrone electrodes, and capillary glass electrodes. The hydrogen-ion concentration is ordinarily very uniform in a given lot of larvae. Different lots differ somewhat. If the blood is exposed to the air the alkalinity increases steadily (rate of 0.2 unit per half-hour in *Chironomus*), probably owing to escape of CO_2 from blood buffers. If the bled larvae are left in their blood, the latter becomes steadily more acid, owing presumably to accumulation of acid metabolites from the tissues. However, if the blood is covered with a 5-mm. layer of paraffin oil the hydrogen-ion concentration remains nearly constant. In both *Sciara* and *Chironomus* certain regions of the gut have a concentration remarkably high and other regions low. All this is an indication that great care must be given to the buffering solutions that are to be used in examining living insect tissues *in vitro*.

EFFECTS OF LOW TEMPERATURES ON CHROMOSOMES

In studies of the salivary gland chromosomes of *Chironomus* it has been found by Dr. J. B. Buck and Miss A. M. Melland that when fresh nuclei are rapidly frozen at -70°C and then thawed, the chromosomes are almost invariably disrupted and the entire nucleus is filled with narrow parallel ridges or striations, which appear to be due to the formation of needle-like ice crystals in parallel orientation. The striations may occur at any temperature between -70° and -30°C , though less frequently at the latter. These striations are found to be due to the low temperature. It could be shown that the cause was not the thawing process or the dissection medium. Also the amount of water in the chromosomes seems to regulate the amount of disruption. As the water decreases, the disruption and striation is less marked.

It is of interest to note that freezing and disruption of the chromosome do not denature the nuclear proteins. These still react to solutions of various osmotic concentrations by shrinking and swelling reversibly. Freezing thus produces a physical rather than a chemical change. A sequence of this is that in order to be isotonic with the chromosomes, a solution need be only half as concentrated after the gland is frozen. Normally the cytoplasm serves as an osmotic insulator to the nucleus, and its disruption breaks down the barrier.

TECHNICAL NOTES

In connection with the investigation of the molecular structure of the chromosome undertaken in cooperation with Professor Astbury under a grant from the Rockefeller Foundation, Miss A. M. Melland has spent the past two years in this laboratory working in the Metz group. She has been able to develop the difficult technique of isolation of salivary

gland nuclei and thus provide sufficient material for analysis and experimentation. Her chief material consisted of *Chironomus*, which has nuclei up to 100 micra in diameter. The glands are detached either in isotonic Ringer's or in the body fluid of the larva, and the nuclei dissected out with fine steel needles. Using unfixed glands, it was found that with glands that had been in a 0.25 per cent solution of dried egg albumen for 2 to 3 hours at 5° C the nuclei could be satisfactorily dissected out on an ice-cooled stage. With glands that had been fixed over osmium vapor, the nuclei could be dissected out in distilled water, and such nuclei show no shrinkage of the

chromosomes. Also glands that had been fixed in 10 per cent formalin yielded satisfactory nuclei that could be dissected out at the rate of 50 to 80 nuclei per hour.

In this connection mention might be made of the small electrical paraffin bath which was devised by Dr. J. B. Buck while a National Research Council Fellow at the California Institute of Technology. With this device one can embed objects 200 micra or less in paraffin and maintain accurate orientation. It should be a useful instrument for workers who require orientation of their material but are not equipped for elaborate microtomic techniques.

THE CHROMOSOME AND GENETICS

CHROMOSOME REARRANGEMENT

Former attempts in this laboratory to induce mutations in *Sciara* by means of irradiation resulted in very few mutants, and the conclusion was being arrived at that this species is more resistant to X-ray and radium than other flies. During the past year it was discovered that this was because mostly females had been used. When males are irradiated, mutations are readily obtained. This material has been studied by Dr. Metz and Dr. Boche with a view to the significance of the results in terms of the physical characteristics of the chromosomes and the possible bearing of the phenomena on the question of the relation between "gene mutation" and visible chromosome rearrangement. They have had the assistance of Dr. Maxwell of the Bureau of Chemistry and Soils, U. S. Department of Agriculture, in giving X-ray treatments, and of the staff of the Kelly Hospital in Baltimore for the radium treatments.

With respect to chromosome rearrangements in treated males, it was found that out of 104 larvae, 28 were

clearly affected, that is, 27 per cent. With treated virgin females, 216 larvae were either unaffected or not satisfactory for study. No evidence of rearrangement was found in any of the material from treated virgin females. This extreme difference in the response of germ cells in the two sexes is not regarded as a specific sex difference. The investigators point out that in *Sciara* the eggs of any female all mature at once and are nearly mature when she emerges. Thus only mature or nearly mature eggs are irradiated. In *Drosophila*, oöcytes and oögonia in all stages are irradiated simultaneously. In the latter species, therefore, rearrangements are easily obtained in female material, as they are also in male material in *Sciara*.

The difference between the frequency of chromosome rearrangement in sperms and that in eggs is attributed by these investigators to the physical characteristics of the chromosomes. In sperms the chromosomes are packed closely together, perhaps somewhat diffusely and with little matrix separating them. These conditions give an opportunity for broken ends, caused by irradiation, to

unite in new combinations and produce rearrangements. In eggs, on the other hand, the chromosomes are not in such close proximity as in the sperms, and the separating matrix appears to be sufficiently resistant to prevent broken ends from forming new combinations. The interesting observation should be added that chromosome rearrangement and "gene mutation" are alike in being produced readily by treating sperms but not by treating eggs. It is therefore unlikely that there is any essential difference in the initial process in the production of the two.

The possibilities of translocations, deletions, duplications, inversions, ring chromosomes, and other forms of recombinations have been reviewed from a theoretical standpoint by Dr. J. B. Buck on the basis of a break in two synapsed homologous chromosomes coiled into a helix. Such a break would divide the chromosomes into six fragments, which he points out could rejoin two by two in 105 different ways. Other combinations may result if the synapsed coiled chromosomes are sister chromatids instead of homologues. Also, if a single coiled chromosome is considered to break at contiguous spots in four adjacent coils, another large group of recombinations is possible. In other words, one break in a coiled chromosome may produce the equivalent of two or more simultaneous breaks at widely separated points.

EVOLUTIONARY CHANGES IN CHROMOSOMES

In an attempt to find morphological changes of evolutionary significance in chromosomes, Dr. Metz has centered attention on the small chromosomal differences that exist in closely related species, and for the most part a few species of *Sciara*. In view of the evidence that many, if not most, mutations result from mechanical chromosome re-

arrangements, it is concluded that the low frequency of mutation in *Sciara* is due to its low rate of rearrangement. As seen above, rearrangements do occur in *Sciara* but they are much less frequent than in *Drosophila*, and *Sciara* is that much more stable in its chromosome organization. The large size of the salivary gland chromosomes makes it possible to compare the makeup of homologous chromosomes from two parents, whether of the same or of different strains. It has been found that structural differences fall into two categories: gross differences, such as usually mark chromosome rearrangements, and small differences which involve only one or very few of the transverse chromatic discs, i.e. single-band differences, and it is these that have been especially studied. In *Drosophila* the gross differences are common and the small differences seem to be rare, whereas in *Sciara* the opposite is true. From what evidence he has been able to collect, Dr. Metz is of the guarded opinion that the more drastic evolutionary changes result from the gross differences and the smaller or more gradual changes result from the smaller type.

In *Sciara*, throughout most of its fourteen species, there occurs in the germ-line cells a peculiar large chromosome known as the "limited" chromosome. It is eliminated from somatic cells during early embryonic stages. This chromosome appears to be relatively "empty" but always large. In two species of *Sciara* the "limited" chromosome is not found and it appears that its vital parts have been transferred to one or more of the other four chromosomes, without, however, producing any obvious change in their appearance. If genes can be transferred in that manner, they must take up relatively little space in their new locations. Finally, another unstable condition marks *Sciara*, namely the different types of sex ratio, unisexual, bi-

sexual, and mixtures of the two. Dr. Metz concludes from his data on these ratios that there is a relatively slight difference between the modes of production of "unisexual" and "bisexual" progenies. The exact nature of this genetic difference would be of very great interest, and this feature is now being studied.

INHERITANCE AND SEX DETERMINATION IN SCIARA

The genetic and cytological peculiarities of *Sciara* have engaged the attention of Dr. Metz and his co-workers more or less continuously since 1925 and have proved a fruitful source of fundamental data on the part played by chromosomes in inheritance. During the past year he has gone over this whole period and has prepared a review in which his observations are interpreted so as to be applicable to other organisms, and in which the extent of divergence between *Sciara* and other forms is clarified. Certain peculiarities in *Sciara* have importance in that they throw light on subjects of general biological interest. The review has the added value of providing an opportunity for the correction of earlier misinterpretations. Among the interesting features of *Sciara* is its peculiar and complicated mechanism of sex determination: the production of unisexual families, to which reference has already been made, the uniparental inheritance through the male, the "limited" chromosomes present in the germ line but not in somatic tissues, and the precise elimination processes which remove certain chromosomes during embryonic development and others during spermatogenesis. If we are to understand genetics, these phenomena which have become so thoroughly established in *Sciara* will have to be taken into account.

STUDIES ON SPECIES HYBRIDS

Observations have been made by Dr. Metz and Miss H. V. Crouse on indi-

vidual species and on species hybrids which confirm their previous experience that gross chromosome rearrangements (translocations and inversions) are rare in *Sciara*, whereas minute or single-band chromosome changes are common. This provides an explanation for the low mutation rate in *Sciara* in contrast with *Drosophila*, where the reverse condition prevails. In two species of *Sciara* (*S. ocellaris* and *S. reynoldsi*) the chromosomes differ not only in structure but also in physical consistency. With this there is associated an apparent difference in their response to irradiation. With the *ocellaris* male and *reynoldsi* female no offspring were obtained, though they copulated readily and sperm was transferred normally. The reciprocal mating resulted in offspring, of which all females were sterile but some of the males were fertile. This result is attributed to the different strains which characterize *S. ocellaris*. In the bisexual strain of that species the chromosomes have the form of 4 rods, 2 small V's, and 2 large V's, as in *S. reynoldsi*. But in the unisexual strain the chromosomes may have the form either of 6 rods or of 5 rods with a corresponding alteration in the number of V's present.

A RECURRENT, SPONTANEOUS CHROMOSOME BREAK IN SCIARA

In a certain wild-type strain of *Sciara ocellaris*, Dr. Metz has found that the salivary gland nuclei of numerous individuals are characterized by having a transverse break in one member of chromosome pair A and at a definite locus. It appears to involve a small deficiency. The break is present in all the salivary gland cells of the affected individual but is not found in any of the ovarian cells of the same individual, and therefore probably occurs early during ontogeny. No case was found in which both homologues were broken. The condition ap-

pears to be inherited, and about one-half of the offspring from a pair mating show the effect.

PARASITIC INFECTION IN DROSOPHILA

The life history of a small hymenopter (*Eucoila drosophilae*) which parasitizes various species of *Drosophila* has been studied and described by Dr. R. D. Boche. This parasite came to his attention during breeding experiments, and in addition to its interesting life history it may be of importance to those main-

taining large stocks of *Drosophila* for genetic studies. After the host develops through pupation and the imaginal disc is well under way, the parasite becomes a grub and consumes the host tissue, whereon it undergoes metamorphosis and emerges as an adult wasp, the total period of development occupying 18 to 20 days. All strains of *D. melanogaster* tested were found to be susceptible to development of this parasite. Some species of *Drosophila*, however, were found to be immune.

TISSUE CULTURE AND TRANSPLANTATION

EVIDENCE FROM TISSUE CULTURES REGARDING CANCER

As a participant in a symposium on cancer, Dr. W. H. Lewis has assembled his data obtained from the study of tissue cultures bearing on the nature of cancer. The occurrence of bacterial and virus tumors has made it difficult to decide whether cancer cells are permanently altered cells that are able to multiply independently of the particular environment or agents that induced them, or whether they are cancer cells because they harbor an agent which increases as they increase and which is responsible for their continued existence. Dr. Lewis has helped to clarify this problem by drawing a sharp line between the malignant cells produced by viruses and true neoplasms. The former behave like malignant cells because they harbor a virus, but they are not to be regarded as new-cell types until they are virus-free. After several years of observations on rat tumors, of which mention has been made in these reports, Dr. Lewis finds, first, that in all the sarcomas thus far studied the malignant cells differ visibly from any normal cells appearing in cultures, and moreover they differ one from another. Secondly, they maintain their peculiar cytological characteristics

as well as their malignancy when transplanted serially from animal to animal, and also in vitro when cultivated in pure colonies for long periods of time. Finally, the inoculation of such colonies into rats produces typical tumors from which in turn typical malignant cells can be obtained again in cultures. This pretty well justifies the conclusion that such malignant cells are mutant or new-cell types.

At this point I must enter a delayed note regarding the finished study of pinocytosis in malignant cells, which Dr. Lewis completed in 1937. Excellent photographs of this remarkable phenomenon accompanied a complete description and discussion. That pinocytosis occurs in malignant sarcoma cells as actively as in macrophages is an index of its general bearing on the physiology of the cell and the tissue fluids.

CULTURAL AND CYTOLOGICAL DIFFERENCES BETWEEN NORMAL AND MALIGNANT CELLS

As we have just seen, the malignant cell is a permanently altered one, and with experience its special characteristics can be identified. But these visible changes are slight and vary from tumor to tumor. For that reason a survey of all such differences has been made by Dr.

W. H. Lewis. He is unable to find any one cytological difference that will distinguish the normal fibroblast from all malignant sarcoma cells. However, each type of malignant cell usually has one or more characteristics that distinguish it from the normal cell, and with experience a discrimination between the two can be made. The most common characteristics of the malignant cells are: increase in size of cell and nucleus; increase in density of cytoplasm; increase in number and decrease in size of mitochondria; increase in the amount of nucleolar material; increase in thickness of nuclear membrane and granular condition of the nucleoplasm. In addition to some differences in pattern, cultures of malignant cells tend to liquefy plasma clots much more than do normal ones. Auto- and homoplasma clots are more readily liquefied than chicken plasma ones. These differences do not always occur. Malignant cells do not always liquefy plasma, and on the other hand colonies of normal cells sometimes produce liquefied circles in homo- or autoplasma and occasionally in the thin chicken plasma clots of roller tube cultures.

TWO NEW TYPES OF TRANSPLANTABLE TUMORS

Among the many tumors that were induced by Dr. M. R. Lewis in mice in this laboratory during the past year were three lymphosarcomata (Carnegie 172, 226, and 233). They are of particular interest because they arose at the site of an injection of dibenzanthracene and were studied as transplanted sarcomata and not as blood diseases. They arose 75, 115, and 237 days respectively after the injection. Microscopically they consisted of malignant lymphocytes. Two of them arose from the axillary lymph nodes and one from the thymus. A fourth transplantable lymphatic tumor (Carnegie

284) arose in a mediastinal lymph node, invading the lungs and heart. It was transplanted by subcutaneous implantation of whole blood or bits of blood organs or of the tumor through many generations in mice of the same strain. It would not grow in other strains. In some instances this tumor exhibited characteristics of lymphatic leukemia. One of the lymphosarcomata (Carnegie 172) was transplanted through 12 generations in mice of the strain in which it originated. It was 100 per cent transplantable in mice of its own strain but not transplantable in others. Pieces of lung, liver, spleen, kidney, lymph node, or tumor as implants carried the tumor, but neither blood plasma nor the supernatant fluid of centrifugalized extracts of the tumor resulted in tumors.

A slow-growing tumor of unusual interest (Carnegie, monocytoma 255) was discovered by Dr. M. R. Lewis in the spleen of a mouse. Near by, attached to the peritoneum, was another tumor, a cystic sarcoma, which apparently had been induced by an intraperitoneal injection of dibenzanthracene 411 days previously. The splenic tumor, to which Dr. Lewis directed her special attention, was found to consist of malignant cells of the monocyte type, for the most part being permanently altered large epithelioid cells and macrophages. The tumor was therefore designated a monocytoma, a counterpart of the tumor of the same name occurring in human beings. Transplantation revealed that the tumor is readily transplantable in mice of the same strain, and it was shown to be the living cells that were necessary for such transfer. When implanted subcutaneously the resulting tumor invaded the muscles and surrounding tissue; when implanted intraperitoneally it invaded the various abdominal organs. Frequently the hosts of transplanted monocytoma remained free from lesions other than the subcutaneous tumor, although

the spleen enlarged. After the tumor had grown for a month or longer, metastases appeared, first in the liver, later in the spleen, thymus, and bronchial lymph nodes. When metastases were implanted subcutaneously, tumors resembling the original monocytoma developed at the injection site, irrespective of the organ from which the metastasis was removed. The growth of the tumor did not result in any marked changes in the blood of the host. Where the tumor reached a large size there was some leucocytosis, consisting in increase in monocytes. Malignant cells, however, that were present in the blood at the time of its injection into normal mice resulted in a monocytoma at the injection site, whereas blood deprived of its cell content did not produce a tumor.

INERTNESS OF SULFANILAMIDE IN CAUSING TUMORS

Because sulfanilamide, which is now employed so frequently in the treatment of infections, resembles in its chemical form certain known carcinogenic substances, the possibility was seen that its use might result in undesired tumors. This has been given a thorough test by Dr. M. R. Lewis. Using 2- to 3-month-old mice, she injected a sterile olive oil suspension of sulfanilamide in the axilla, in a way similar to that used for the production of dibenzanthracene tumors and in amounts equivalent to the amount used in the course of treatment of a bacterial infection. This did not bring about the development of tumors. The majority of the mice were kept 300 days after injection and none of them developed tumors, although of 75 mice that had been injected with dibenzanthracene at about the same time 35 developed tumors within 214 days. The 300-day sulfanilamide mice which had not developed tumors were again injected and fragments of tumors were implanted along

with the sulfanilamide. In each case these tumors grew, proving that the sulfanilamide had not made the animals refractory to tumor growth.

As another approach, mice having either spontaneous tumors or tumors induced by dibenzanthracene were given subcutaneous injections of sulfanilamide without any sign of regression of the tumors. Also it was found that the subcutaneous injection of a sulfanilamide solution into mice prior to and following the implantation of a tumor did not prevent the growth of the implanted tumor, nor did it cause any change in the transplantability or strain specificity of the tumors. It thus is evident that sulfanilamide is inert with respect to tumors.

A REVIEW OF TISSUE CULTURE STUDIES OF WHITE BLOOD CELLS

As a contribution to the volume on *Cooperation in research*, published on the occasion of the retirement of Dr. John C. Merriam as President of the Carnegie Institution, Dr. W. H. Lewis and Dr. M. R. Lewis prepared a discussion of the fifty-two papers which they and their associates have published during the past twenty years on the nature of white blood cells. This covers the exciting period during which the new techniques of tissue culture and other methods made it possible to return to the study of living cells and to observe normal and experimentally induced details that were unknown to the early hematologists, studies in which the two Lewises have taken a conspicuous part. Their review of the origin and relationships of the blood cells will be of importance to workers in this field. As might be expected, the larger part of their discussion is devoted to their more recent work, namely, their studies on the locomotion of blood cells, abnormal and malignant white blood cells, and the blood picture of tumor-bearing mice.

TRANSPLANTATION OF EYE RUDIMENT IN *DROSOPHILA* LARVAE

During the past year there has appeared an account of the transplantation experiments of Dr. J. B. Buck, carried out in collaboration with Dr. G. Gottschewski at the California Institute of Technology. Using two forms of *Drosophila* hosts of different genetic constitution, they transplanted in them in various combinations a series of larval eye rudiments having six different eye-color potentials and observed the eventual color of the implanted eye. For the most part there were 10 or more successful specimens for each combination. In this way they secured information regarding the nature of the host factors; on

the one hand, and the factors inherent in the implanted rudiment, on the other, that are involved in eye-color characteristics. This type of larval transplantation (Beadle and Ephrussi) has introduced some new points of view, and the extent to which the embryologist and geneticist will be able to utilize them is as yet unknown. Because of the rather heavy injection of new theoretical considerations and laboratory symbolism, the uninitiated person is to be warned that he may find himself bewildered in trying to follow these investigators to their final conclusions or to comprehend what their conclusions actually are. There is no harm in this if it eventually leads us to a better understanding of organogenesis.

BIOCHEMICAL STUDIES OF SECRETION

CEREBROSPINAL FLUID OF THE FETAL PIG

In order to throw further light on the controversy as to whether the cerebrospinal fluid is an ultrafiltrate or dialyzate of the blood plasma or whether it is a secretion involving energy expenditure by the cells of the chorioid plexus, Dr. L. B. Flexner has made a study of a phase of ultrafiltration and a phase of secretion occurring in the same animal. He has studied the chemical relations between cerebrospinal fluid and blood plasma in different stages of fetal development and thus is able to determine what difference is introduced with the functional maturity of the chorioid plexus. His work was greatly aided by the generous cooperation of the Bureau of Animal Industry, U. S. Department of Agriculture.

It was found by Dr. Flexner that in pig fetuses up to a crown-rump length of 5.0 cm. (about 40 days), the distribution of chlorine, sodium, and urea in the cerebrospinal fluid is in equilibrium with the plasma. The only energy neces-

sary for the formation of this fluid can be supplied by the heart, and the fluid may therefore be considered an ultrafiltrate of the plasma. In fetuses having a crown-rump length of 5.0 to 6.0 cm. (40 to 43 days), the chlorine, sodium, and urea attain distribution ratios like those in adult animals. These substances in these older fetuses are so far removed from equilibrium with the plasma that the heart energy is not enough to account for the formation of the fluid. Consequently ultrafiltration is now not an adequate explanation. The extra energy must obviously be supplied by the principal source of the cerebrospinal fluid, namely the chorioid plexus, and the fluid must be regarded as a secretion of the plexus.

BIOCHEMICAL CHANGES ASSOCIATED WITH BEGINNING FUNCTION OF THE CHORIOID PLEXUS

The completed account of the investigations of Dr. L. B. Flexner on the changes in the fetal chorioid plexus at

the onset of secretion has been published during the past year. In brief, these changes are as follows: Before secretion starts, indophenol oxidase is in equal concentration in epithelium and stroma. With the onset of secretion this oxidase becomes concentrated in the epithelium and disappears from the stroma. As a corollary to this, before secretion starts there is no potential difference between epithelium and stroma, but with the onset of secretion a potential difference of 0.100 volt develops, which with age increases to 0.230 volt. With the onset of secretion there is initiated a selective transference of dyes, so that chosen basic dyes pass from stroma to epithelium and chosen acid dyes from epithelium to stroma. The reducing power of stroma increases with age. Along with these chemical changes there occur structural changes in the tissues, notable among which are decrease in the height of the epithelium, tufting and increased vascularization of the secretory plexus, and lessening of the distance between the stroma-epithelium line and the capillaries.

In the departmental report of last year reference was made to the work of Dr. Flexner and Dr. R. D. Stiehler on the problem whether the cerebrospinal fluid is a dialyzate in equilibrium with the blood plasma, or an ultrafiltrate of the blood plasma, or a true secretion involving energy expenditure on the part of living cells. Their conclusions on the mechanism of this secretion have now been published in a complete account. Their results support the hypothesis that the barrier or interface between stroma and epithelium comports itself as a reversible oxidation-reduction system. The electron transfer from stroma to epithelium which completes the electrical circuit is carried by a system which is oxidized by the epithelium and reduced by the stroma. That is, the difference in potential between epithelium and stroma

gives rise to an electric current causing cations to move from stroma to epithelium and anions in the opposite direction. The difference in potential between the stroma of the chorioid plexus and the epithelium is correlated with the inequality of distribution of the indophenol oxidase between these two tissues. Under cyanide anoxia and N_2 asphyxia the potentials of epithelium and stroma become equal. It is thus understandable that basic dyes are selectively transferred from stroma to epithelium and acid dyes in the reverse direction, and that under cyanide or N_2 asphyxia this selective transference is suspended.

BIOCHEMICAL CHANGES AT ONSET OF FUNCTION OF METANEPHROS

Using fetal pigs, Dr. L. B. Flexner has made observations on the chemical changes that occur in the developing kidney as its epithelial tubules begin their secretory functions. He was able to demonstrate that in the earlier stages cytochrome oxidase is present in low concentration but equally distributed in the nephrogenic tissue and the beginning uriniferous tubules, which are not yet connected with the collecting ducts. When secretion begins it becomes highly concentrated in the active uriniferous tubules, the concentration being about the same in the proximal and distal convolutions. It largely disappears from Bowman's capsule and from the kidney stroma and is present only in low concentration in the epithelium of the collecting tubules.

When redox potentials are determined, it is found by Dr. Flexner that in the pre-secretory stage the potentials of the epithelium and stroma are alike. With the onset of secretion the potential of the epithelial tubules rises and that of the stroma falls so that the indicator shows a difference of 0.230 volt between them.

This duplicates the observations previously made on the epithelium and stroma of the chorioid plexus, where also,

with the onset of secretion, the potential of epithelium rises and that of the stroma falls.

PHYSIOLOGY OF REPRODUCTION

EXPERIMENTAL INDUCTION OF OVULATION

During the normal breeding season of the fall and winter months a series of tests were made by Dr. C. G. Hartman on non-ovulating female monkeys with a view to producing ovulation by the injection of appropriate hormones. The results were determined, for the most part, by bimanual palpation. In many cases they were checked by opening the abdomen and inspecting the ovaries. In some cases the ovaries were removed and sectioned for microscopic study.

In over one-third of the cases (32 out of 83) the ovaries gave little or no response. These are refractory cases and practically all of them had been non-ovulating animals when the experiments started. In 7 cases normal follicular enlargement occurred without however advancing to actual ovulation. In 16 cases, the ovaries were greatly overstimulated and in most of them several follicles responded with signs of degeneration and other abnormal conditions. Finally, there were the cases in which ovulation was associated with the use of the hormone; of these, 5 might have ovulated before the administration of the hormone and perhaps should not be included. There were 12 animals that probably would have ovulated without treatment; these also might possibly be eliminated. There remained only 8 experiments in which ovulation with reasonable certainty was due to injection.

It is evident that control of the time of ovulation in monkeys and probably in man is not going to be an easy matter. If an animal is refractory to its own pituitary hormones it is likely to remain refractory to injections of hormonal extracts like gonadogen (Upjohn), folli-

tein (Squibb), and follicle-stimulating hormone (Hisaw), such as were used in these experiments. In his description of these observations on monkeys Dr. Hartman throws out a warning against the use of large quantities of potent hormones in humans because of the damage that might be done to the ovaries. The chance of beneficial effects is so poor that a treatment with such potential disadvantages is scarcely justifiable. However, damage from use of gonadotropic substances is only temporary. It is followed by complete recovery. Apparently the correct dosage is essential, and this is difficult to determine. With any two non-ovulating monkeys which in appearance and behavior may appear the same, it is found that the same dose that in one has no discernible effect, in the other may completely upset the ovaries. The same is doubtless true in women.

FUNCTION OF THE OVARY IN THE MAINTENANCE OF PREGNANCY

It was found by Dr. Hartman that a monkey castrated on the 31st day of gestation continued the pregnancy to the 140th day, at which time a live, vigorous baby was removed by Caesarean section. Four additional animals gave corroborative evidence. It therefore appears that in the monkey the presence of a corpus luteum is not essential after the first month of pregnancy, that is, after the placenta has accomplished its nidation and essential differentiation. Thus in the guinea pig, now the monkey, and probably in man, all of which forms have prolonged gestation periods, the ovary is not required for the maintenance of pregnancy in its later stages. In this respect these forms differ from the rat, mouse,

and rabbit, which invariably abort if the ovaries are removed. In a previous report reference was made to Dr. Snyder's experiments which showed that he could lengthen pregnancy in the rabbit by producing new corpora lutea. In fact, in that species the duration of pregnancy is apparently determined by the duration of activity of the corpora lutea. Perhaps pregnancy could be extended in monkey and in man if toward the end new stimulus could be given to the placental tissues, providing, of course, they include among their functions that of the corpus luteum of the rabbit.

OVULATION, FERTILIZATION, AND TRANSPORT OF EGGS

The discovery of the mammalian oestrous cycle gave great impetus to the study of the physiology of reproduction and along with it the intricately interwoven regulation maintained by the endocrine secretions. This gave origin to a literature so extensive that it could be followed only by those specializing in the subject. The need was met, however, by a series of reviews of the different aspects of the subject written by leading investigators in the respective fields under the editorship of Professor Edgar Allen and published as a volume under the title *Sex and internal secretions*. As was mentioned in Year Book No. 32 (1932-1933), one of the chapters came from the hand of Dr. C. G. Hartman. The importance of this book soon led to the exhaustion of the edition. This gave an opportunity for revision and issue of a second edition. The new material from Dr. Hartman's own work, published for the first time, and his review of the work of other investigators presents a concise, authoritative, and vivid account of ovulation, viability of the egg, fertilization, transport of the ovum and sperm, and related phenomena. The fact that it contains other chapters of this

character makes this volume a fundamental one for workers in the physiology of reproduction.

RELAXATION OF THE PELVIC LIGAMENTS DURING PREGNANCY

Dating back to 1932, observations have been made by Dr. W. L. Straus, Jr., and Dr. C. G. Hartman on the ligaments of the sacroiliac joints and the pubic symphysis of monkeys during pregnancy. It has been found that a relaxation of the pelvic ligaments is an invariable characteristic of the last six weeks of pregnancy in both the macaque and the bonnet monkey, and that within three or four weeks after delivery the ligaments revert to their former condition. The test used for determining the mobility of the pelvic bones was the distance the ischial tuberosities could be spread apart by traction, measured by calipers in millimeters. In the nonpregnant females this capacity for spreading may amount to 1.0 to 4.0 mm., and during pregnancy it increases to 10.0 to 18.0 mm. The histological alterations that accompany this relaxation are in the nature of an edema. Presumably there are hormonal factors regulating this. It is clear that the ovary is not the responsible agent, since castration during early pregnancy does not prevent the phenomenon, nor does death of the fetus.

FUNCTIONAL VIABILITY OF SPERMATOZOA OF GUINEA PIG

As a means of determining the length of time spermatozoa can remain in the female genital tract and retain their power of fertilizing ova, Dr. J. K. Lamar utilized artificial insemination of guinea pigs at intervals of 2 to 30 hours before the onset of heat, which is equivalent to 12 to 40 hours before ovulation. The most satisfactory method of artificial insemination was found to be the injection, by means of a glass speculum and

pipette, of undiluted sperms from the vas deferens into the cervix uteri.

It was found that the longest time before ovulation that sperms survived and were still capable of fertilizing ova was 22½ hours, which is only one-half the time that motility of the sperm persists. Dr. Lamar, under a grant from the National Committee on Maternal Health, has been a guest of this laboratory during the past year in association with Dr. Hartman.

OBSERVATIONS ON THE BONNET MACAQUE

As a supplement to his much larger collection of records on the rhesus monkey, Dr. C. G. Hartman has had an opportunity to observe, over a considerable period of time, a group of bonnet macaques (*Macaca radiata*) consisting of 8 large males and 8 mature females. One of the latter underwent three successive pregnancies, two of them having gestation periods of 153 and 169 days respectively. In its menstrual cycle and period of gestation the bonnet macaque resembles the rhesus monkeys. It shows an individuality in its sex skin, which, ordinarily inconspicuous, becomes greatly swollen during the later weeks in pregnancy after the manner of the anthropoids. In their mating habits the bonnets exhibit a more restricted period of receptivity than the rhesus females. It is largely limited to the mid-interval between menstrual periods. Castrated females, however, mate freely when they are receiving injections of oestrin. During pregnancy mating was seen only during the first seven weeks.

STUDIES OF REPRODUCTION IN AMERICAN MONKEYS

Dr. G. W. D. Hamlett, who has been associated with Dr. Hartman in some of his studies on reproduction, returned last year from a two years' visit in South America under a Guggenheim Fellowship. While there he made observations on

the cebus monkey in captivity under conditions more or less like those of the macaques of Dr. Hartman's colony. He was able to show that the cebus exhibits a regular oestrous cycle of 16 to 20 days that is detectable by vaginal washings. Ovulation occurs at about the time of maximum vaginal desquamation. Menstrual bleeding is common and in some females occurs in most cycles. It occurs when desquamation is at its lowest and may last from 1 to 5 days. Following ovulation there occurs a sudden massive invasion of leucocytes into the vaginal canal. The cebus seems to differ from the macaque in having a very short non-breeding season. Birth of young monkeys, however, is bimodal, occurring more frequently at two times of the year, May and October.

Reference may be added to Dr. Hamlett's observations on the reproductive cycle of the coyote. In a cooperative undertaking between the U. S. Department of Agriculture, Section of Fur Resources, and our laboratory a study has been made of the reproductive tracts of fur animals sent to our laboratory by field men of the government. Examination of this material by Dr. Hamlett reveals that the breeding season of the coyote is limited to a small part of the year. This conclusion is based on the histological state of the ovaries and testes. According to the signs of activity in the sex glands, the male is sterile at least eight months of the year; the female during at least ten. This material was collected from thirteen of the far western states.

GENITAL SWELLING IN THE PREGNANT ORANG

Cyclic swelling of the sex skin of females, related to oestrus, characterizes most of the primates. There are, however, two notable exceptions, the gibbon and orang-utan. Dr. A. H. Schultz through his participation in the Asiatic

Primate Expedition had an opportunity to study both of these exceptional forms. Among 40 wild, fully adult female gibbons, in all stages of the sex cycle and several pregnant, he found none that showed any swelling of the sex skin. Of 3 adult female orang-utans, however, one was in a late stage of pregnancy and showed an extensive genital swelling which was absent in the two nonpreg-

nant specimens. By studying reports from zoological gardens Dr. Schultz has been able to collect 4 other cases, and it is apparent that sex-skin swelling is a regular characteristic of pregnancy in the orang-utan, though it is restricted to that period. If genital swelling is taken as an index of position on our ancestral phylogenetic tree, this brings man and gibbon to the topmost branches.

ENDOCRINE STUDIES

PRODUCTION OF PROLAN IN TISSUE CULTURE

Dr. G. O. Gey working in cooperation with Dr. Seegar and Dr. Hellman has succeeded in growing cultures of tissues from a placenta of three months and from a hydatidiform mole. Before its assay the placental culture had been maintained for 2 months; the mole had only been in culture for 9 days. The demonstration of the production of prolan by the cultured cells was made by combining the fluids of the placenta and the hydatidiform mole cells. Five tubes of placental tissue containing about twenty fragments each, and four tubes of mole containing about ten fragments each, yielded all together 4 ml., which in doses of 0.6 ml. was injected in test rats twice daily for three days. The rats were opened and the ovaries examined on the fifth day. They showed a strongly positive reaction for prolan, each ovary having several blood points.

Later the placental cultures and the mole cultures were tested separately and they were both positive for prolan. When the supernatant fluid from the placental growths was tested it gave no reaction, whereas the fluid from the mole was strongly positive, producing large follicles in the ovary and swelling of the uterus. If there was any doubt that the placenta produces the hormone prolan, that doubt should be removed by this

demonstration of placental cells growing for a period of over 2 months in tissue culture and still being able to produce the hormone in vitro.

OESTRIN EXPERIMENTS

Eight adult rats were injected with oestrin by Dr. J. Ball for 2 months for the purpose of determining its effect on the sex physiology of the animals. When oestrin is given to castrated females it produces the anatomical and behavioral changes characteristic of oestrus. But in the normal, intact animal it was found by these experiments that administration of oestrin flattens out the normal changes in sexual excitability and under those circumstances acts as a sex depressant. During the injection period quantitative measurement of sexual response gave a rating of 0 to 3 on a scale of 12 according to which the variation in normal heat periods has been found to rate from 7 to 12. Vaginal smears were taken throughout the experiment and it was found that they lost their cyclic character. They consisted for the most part of cornified cells, though at times there was a partial return to the normal cycle, evidenced by the return of leucocytes. There seemed to be a variation in the smear changes according to the strain of rats.

Working in cooperation with Dr. Hartman, Dr. Ball has studied a case of

ovulation in a monkey which apparently was delayed by the injection of oestrin during the first part of the menstrual cycle. A complete record of the animal's sexual receptivity had been kept for several months back. Following increasing daily injections of oestrin (progynon-B Shering) for 6 successive days two phenomena were found to occur: there was an increase in sex responsiveness and there was a delay in ovulation to day 29, this being subsequently confirmed by laparotomy. Of 400 ovulations recorded in the Carnegie colony, this is only the 6th that has occurred later than day 16. The increased sex interest and the growth of the follicle were concurrent and doubtless related, but they may not have resulted directly from the injected oestrin. The investigators have analyzed the various factors and it is their conclusion that the ovulation and increased sex interest were a normal response to the animal's own hormones. Whatever the injected oestrin did must have been through an unknown intermediary.

TESTOSTERONE EXPERIMENTS

In a series of castrated female rhesus monkeys Dr. C. G. Hartman tested the effect of combining the administration of testosterone with oestrone as compared with the administration of progesterone with oestrone, and then he combined the administration of all three. In the latter experiment it was found that testosterone did not inhibit the effect of progesterone and on the contrary seemed to abet it. Twelve animals were used in these experiments. In 6 of them the hormones were administered hypodermically in oil. In the other 6 the same hormones were given in crystalline form as subcutaneous pellets. Administration by pellets proved essentially as effective as when the substances are injected in oil. The extended period of absorption provided by the use of pellets may prove the deciding factor in their favor.

Continuing his observations on the action of sex hormones on reptiles, Dr. T. R. Forbes has tested the action of testosterone on young female alligators. Starting with animals 3 months old, intraperitoneal injections were made during a 91-day period, at the end of which time the reproductive tracts were preserved for microscopic study. The result of the total injection of 10 mg. of testosterone given in this manner was a uniform and striking growth and differentiation of the female oviducts. In a single male specimen there was marked hypertrophy of the penis. It is of interest to add that injections of testosterone were found to have no effect on the clitoris of the female, nor on the Wolffian duct or mesonephros of either sex. The student of embryology is looking for just such factors in development because they reveal the early specificity of tissues and at the same time their dependence on the stimulus of the surrounding substances.

THE ADRENAL CORTEX

Seeking evidence as to whether the adrenal cortex has any influence on the development of the reproductive system, Dr. Gersh and Dr. A. Grollman have conducted a series of experiments on rats and mice which leads them to conclude that the adrenal has no "androgenic" function in the normal animal. The adrenal gland was removed without effect on the development of the prostate and Cowper's glands. Also the effect of castration upon the development of the prostate gland and of Cowper's gland in animals devoid of the adrenal is essentially the same as that of castration alone. When the adrenal is removed it is necessary to resort to replacement therapy, that is, oral administration of the cortical hormone. It might be objected that this had supplied an androgen which served the developmental requirements of the secondary sex organs. Therefore another series of experiments

was necessary to test the effect on development of giving cortical hormone orally. It was found that the tubules of the prostate gland and of Cowper's gland and the seminal vesicles in castrated mice develop no better even where relatively large doses of the hormone are given. The experiments would seem to prove conclusively the absence of any androgenic activity on the part of the x-zone or cortical zone of the adrenal, and these investigators are inclined to explain the pathological conditions of pseudohermaphroditism and the adreno-genital syndrome occurring in adults as due to the presence of displaced embryonic testicular tissue in the adrenal.

Working in another direction, Dr. Gersh and Dr. Grollman have studied the structural and functional changes that occur in the kidney in rats, cats, and dogs when the adrenal is removed. In the kidneys and also in the livers of their experimental animals they have failed to find any structural changes that can be attributed to adrenal cortical insufficiency. Nor do histochemical studies of the kidney of rats in early stages of adrenal cortical insufficiency reveal any structural or functional pathology. However, when the insuffi-

ciency has become marked there is found to be a demonstrable increase in the rate of reabsorption of water through the tubule. In advanced stages the passage of water through the glomerular membrane is slowed down or entirely discontinued. These are evidently physiological compensatory mechanisms whereby excessive loss of body fluid is prevented. Though there are no demonstrable lesions of the kidney, there ensue disturbances in its function associated with the altered balances between the intake of water and salts by the body and the amounts lost through the secretions and also alterations in the water and electrolyte distribution in the blood as compared with the extra-cellular spaces and the shift between the extra- and intracellular spaces. Finally, in advanced adrenal cortical insufficiency the kidney shows the results of changes in carbohydrate metabolism, in oxygen consumption, and in blood volume. The last item results in reduction of blood pressure, decrease in the amount of glomerular fluid, and decrease in the number of glomeruli that are active, culminating in the cessation of the passage of water across the glomerular membrane.

INVESTIGATIONS OF THE HYPOPHYSIS

AN ATTEMPT TO STIMULATE THE HYPOPHYSIS IN STERILE MONKEYS

Since in our colony of rhesus monkeys there are always some sterile adult female animals, the experiment was made by Dr. C. G. Hartman, with the assistance of Dr. C. Smith of the Department of Roentgenology of the Johns Hopkins Hospital, of trying to stimulate the hypophysis and in this way induce hormonal effects in the reproductive tract which might bring about ovulation. Thirteen adult monkeys in good physical condition were given a single dose of

X-ray of suitable strength (60 to 400 r), with the result that those not ovulating before radiation remained refractory and did not ovulate during the remainder of the season. Nor was there any decisive change in the reproductive tract in any of the animals that could be recognized by palpation. The treatment apparently did not injure the animals in any way and in one-third of the cases spontaneous ovulation and conception occurred in the following breeding season. These experiments should be of value to physicians who are attempting cure

of sterility in women by means of what they call stimulating doses of X-rays.

SECRETORY CELLS OF NEURAL LOBE OF HYPOPHYSIS

In previous reports there has been occasion to refer to the studies of Dr. I. Gersh on the parenchymatous cells of the posterior or neural lobe of the hypophysis, and his discovery that their number is correlated with the dietary intake of water and that their fluctuation in number can be controlled experimentally. When his animals are restricted to a relatively dry diet for a week these cells are present in greater number and are larger. When, on the other hand, the dehydrated animals are given free access to water, the number and size drop back to the normal state prevailing in untreated animals. It was found that among these parenchymatous cells there are many that are undifferentiated but are capable of hyperplasia in response to the stimulus leading to hypersecretion. Thus the differentiated and undifferentiated varieties vary inversely in number. During the past year Dr. Gersh has completed a full account of these glandular parenchymatous cells and the characteristics that distinguish them from neuroglia cells elsewhere in the central nervous system. He finds them present in all mammalian orders whose posterior lobe yields the anti-diuretic substance. The facts that the distribution of these cells corresponds exactly to the location yielding the anti-diuretic substance and that cytological changes occur in them in direct proportion to the rate of secretion of the anti-diuretic substance into the blood stream lead him to the conclusion that these parenchymatous glandular elements of

the neural lobe of the hypophysis are the cells that secrete the antidiuretic substance.

After many experiments a satisfactory method has been devised by Dr. M. R. Lewis and Mr. C. H. Miller for the fixation and staining of the granular cells of the neural lobe of the hypophysis and also the granular cells of the pars intermedia and of the pars anterior. This makes it possible to prepare permanent sections in which these secretory cells retain the appearance that characterizes them in fresh tissue and in tissue cultures. The method is proving of value in the hypophyscal work being done in this laboratory.

ABSENCE OF HORMONES IN TISSUE CULTURE OF THE HYPOPHYSIS

While Dr. Gey and his collaborators were succeeding in making cultures of placental cells that could manufacture a demonstrable amount of the prolactin hormone, Dr. M. R. Lewis in cooperation with Dr. W. C. Cutting made the effort to produce hormones in cultures of the hypophysis. The tissue was grown from 50 to 80 days and at intervals of 2 to 5 days the nutrient fluid was poured off and preserved for testing. Eventually the cultures themselves were injected. The tests consisted in injecting the material in virgin guinea pigs, which on the 5th day were killed and the thyroids, adrenals, and ovaries studied microscopically for evidence of any increased activity. Since no such evidence was seen, it was concluded that the cultured cells under the conditions of their experiment were not manufacturing any thyrotropic, adrenotropic, or gonadotropic hormones.

CENTRAL NERVOUS SYSTEM

MUSCULAR ATROPHY FOLLOWING
DENERVATION

In previous reports attention has been called to the studies of Dr. S. S. Tower on the innervation of skeletal muscle and the factors involved in muscle degeneration which follows interruption of the nerve supply. In the first place, she demonstrated that for most muscles in mammals the simple innervation by a myelinated somatic motor nerve was sufficient to account for its different activities and that the variations in its contractions are produced by variations in the number, rhythm, and intensity of the impulses sent down by the central nervous system. Thus there seemed to be no functional need for any accessory innervation, either sympathetic or of non-myelinated fibers of untraceable origin, the presence of which she was unable to find. This led to the consideration of what is involved in the atrophy and degeneration of muscles and whether normally there are special nerves which exercise a trophic control and so maintain the integrity of muscle fibers. It is the existence of these hypothetical trophic nerves that her work has discredited. In studying a series of cats in which the innervation of one forelimb was partially or completely removed, she was able to demonstrate that cutting the ventral (motor) root was sufficient to establish the complete picture of atrophy and degeneration of the muscle concerned. When the dorsal (sensory) root and sympathetic nerves were also cut there was no evidence of additional atrophy, degeneration, or dystrophy whatever. It was therefore evident that the latter do not participate in the innervation of these muscles in the sense of exercising a trophic control. The fact remained that skeletal muscle undergoes atrophy and degeneration when it is deprived of its nerve supply, and its

trophic control must therefore be attributed to the nervous system.

A review of this whole neurotrophic problem has been made by Dr. Tower during the past year, and by analyzing the nature of the changes taking place in denervated muscle she has done much to clarify the mechanism of their production. In her analysis she systematically reviews the changes in muscle that ensue when its total nerve supply is cut off, including: under physiology, changes in excitability, contractility, fibrillation, and irreversible contracture; under morphology, atrophy, microscopic changes, acute degenerative processes, and fibrous metaplasia; under chemical changes, observations which are thus far relatively scant and of small consequence; and among other factors, the available data on respiratory metabolism of denervated muscle, which throw but little light on trophic control. In addition it was necessary to consider the distinction between the reactions of different animal species, the warm- and cold-blooded animals, and animals of different growth rate and life span, and the variables of procedure followed by different observers. The picture of denervation atrophy is further complicated by physical factors, such as the failure to provide absolute rest for the paralyzed extremity and the prevention of stress and tension on the part of nonparalyzed antagonistic muscles.

With the phenomena of atrophic changes thus reviewed, Dr. Tower proceeds with a summary of the component elements that provide muscle with its nerve supply and their part in the changes that follow denervation. The bulk of the evidence indicates that loss of the motor nerve is the major factor in atrophy of skeletal muscles. The posterior root innervation plays a negligible rôle, likewise the sympathetic. The

muscle spindles, however, behave differently from the ordinary extrafusal fibers. Dr. Tower's observations on the interosseous muscles of cats show that when the ventral roots (motor) are severed, the cross-striated structures degenerate as is characteristic of skeletal muscles; but when the dorsal roots (sensory) are severed, the equatorial nuclei of the spindle undergo atrophic changes.

The reactions of muscle to denervation are classified by Dr. Tower in three phases. There is first a period of inactivity of the denervated muscle, during which both the nervous tissue and, to a slight extent, the muscle degenerate, with definite alterations in muscular function. The second phase is inaugurated by the onset of spontaneous, rhythmical contractions (fibrillation), which then continue as long as the muscle survives. Throughout this phase there is rapid progressive atrophy of the muscle fibers. The third phase is a gradual transition from the second, characterized by the atrophic elimination of the substance of muscle fibers, disappearance of cross striations, and conversion into fibrous tissue incapable either of excitation or of contraction.

On the basis of this sequence, Dr. Tower is able to present the causal factors of muscle atrophy in simplified form. The final atrophy and fibrous metaplasia with any associated degenerative processes are explained as exhaustion of the muscle due to the ceaseless fibrillation. Fibrillation and contracture are the result of earlier changes in excitability and in contractility of the denervated muscle. The denervation therefore is the initiating factor. The nerve is trophic only in the sense that so long as it remains intact the deteriorating sequence which Dr. Tower outlines is avoided. The elimination of any such thing as a specific trophic nerve, concerning the existence of which the work of this investigator

during the past few years has raised grave doubts, appears now to be complete.

INFLUENCE OF POSTURE ON RESPONSE TO CORTICAL STIMULATION

The influence of the posture of muscles on the response they make to stimulation of the cerebral cortex has been studied in the cat by Dr. James W. Ward, who as National Research Council Fellow has been a guest of the Department of Anatomy of the Johns Hopkins University. The element of particular interest was the fact that Dr. Ward brought with him a unipolar electrode which could be more or less permanently inserted at any chosen place on the cortex and the exposed terminal stimulated over a period of weeks in the unanesthetized and unrestrained animal. In 22 cats permanent electrodes were thus placed on the same area of the motor cortex. Repeated experiments performed in this way indicated that under similar conditions of posture and similar strength of stimulus a given cortical point always excited muscular action producing the same final position, whether by rhythmic or non-rhythmic movement. In short, the response from a single cortical point is always similar under the same conditions of posture and stimulation.

When, however, the position of the responding leg is altered prior to the stimulation there is some variation in the order in which the individual muscles are brought into play, though the final position is the same. A given cortical point appears to be more specific for the final position than for the detailed manner in which the position is attained. Variations in latency of response are also correlated with the distance of the initial position of the responding leg from the final position. The latency is greatest when the leg is not far from the final position and shortest when its starting position is

remote. Also the position of the animal's head has an effect on the final position and on the latencies of the responses. Other modifiers of latency and final position were introduced by change of environment and by obliteration of tonic neck reflexes, which can be obtained by severing the nerves to the cervical muscles. We may thus think of a localization of function in the cortex that is constant, providing we regard chiefly the final position of the leg tested and also maintain uniform conditions of posture and environment at the time of stimulation. The interpretation that the differences in latencies which follow altered head position are the result of tonic neck reflexes, acting on the responding leg muscles, cannot be doubted in face of the fact that the differences no longer appear when those neck reflexes are obliterated by the severing of their nerves. But the latency of responses is also markedly influenced by the general emotional state of the animal at the time of stimulation.

INCREASED SPONTANEOUS ACTIVITY FOLLOWING FRONTAL LESIONS

Though uncertainty exists as to the physiological nature of spontaneous activity in animals, and as to the nature of the neural mechanism that is concerned when this activity is increased or decreased, yet it is well recognized that these states constitute phenomena that can be induced and modified experimentally. Recently some investigations on the macaque bearing on this problem have been carried out by Dr. M. Hines in cooperation with Dr. C. Richter of the Henry Phipps Psychiatric Clinic. Increased spontaneous activity had already been observed clinically in man, associated with frontal brain lesions. Dr. Hines and Dr. Richter could make their observations without the limitations inherent in human studies.

By means of a specially devised cage they could accurately record the total activity of their animals. Also they could accurately localize their brain lesions.

As a result of these experiments, it was found first of all that permanent over-activity can be produced in the macaque by removal of the frontal poles of the brain, either on one or on both sides. The parts removed in the experiments giving the best results included the tip of the basal nuclei (caudate and putamen) as well as the prefrontal cortex. Of the different areas of the prefrontal cortex it was found that Brodmann's "area 9" gave the best results. When this was removed on both the right and left sides a definite increase in activity resulted. Unilateral and bilateral removal of other cortical areas of the frontal region had little or no effect on spontaneous activity, unless combined with the removal of the underlying tip of the caudate and putamen nuclei. These investigators thus conclude that spontaneous activity is definitely controlled through area 9 of the prefrontal cortex and through the caudate and putamen of the basal nuclei. Though guarded in their explanation of the mechanism, they suggest that the increased activity is a variety of release phenomenon in which the removal of inhibitory influences from these higher centers permits external stimuli to pass freely, without inhibition, to lower reflex centers.

BEHAVIOR IN FIREFLIES

Group behavior illustrated by the synchronous rhythmic flashing of fireflies would doubtless be regulated by the central nervous system if fireflies had a typical central nervous system. Such being the case, reference may be made here to the studies of Dr. J. B. Buck on the phenomenon of synchronism and rhythm in that insect. In my last report an account is given of his observations

on the spectral composition of the light emitted by fireflies. Since then he has completed an analysis of firefly flashing in which he concludes that the synchronism which characterizes it is sometimes a by-product of signals used in mating and sometimes is due to a "leader" response. It is clearly a complex phenomenon and is greatly modified

in different localities and in different species. Dr. Buck conducted experiments in which he confined males of *Photinus pyralis* in a mosquito-netting cage in a dark room where their behavior was subject to accurate observation and experiment. With this equipment he was able to demonstrate the leadership principle.

COMPARATIVE ANATOMICAL STUDIES

PRIMATE STUDIES

During the past few years, whenever the opportunity arose, Dr. A. H. Schultz has collected data on the weight of the testes and its relation to body weight among different primates. His series was considerably increased by his association with the Asiatic Primate Expedition of 1937, led by Mr. Coolidge, and for the study of this problem he is now able to report on the relative weight of the testes in a total of 82 simian primates. Of these, 12 are New World monkeys and all the others are catarrhines including the higher primates and man. Among the American monkeys the weight of the testes fluctuates between 0.1 and 0.4 per cent of body weight. Of the Old World monkeys, in the five species of macaques the relative testicular weight varies between 0.4 and 0.92, whereas in langurs it is much lower and runs between 0.06 and 0.08. The latter ratio is about that for higher primates, being 0.05 in orangutans and 0.08 in gibbons and in man. The chimpanzee differs from other primates in having a testicular ratio of 0.27. The great difference in these ratios may be realized when it is seen that a bonnet macaque weighing about 17 pounds has slightly heavier testes than a Negro weighing 150 pounds. It was found by Dr. Schultz that where testes are large relative to body size, the increase in size consists principally in tubular mass and the amount of supporting tissues is rela-

tively less. This was determined by making sample microscopic sections of the testes and reconstructing on larger scale the areas occupied by tubules and determining their ratio to areas occupied by the remaining parts. By such calculation it was found that with equal body weight, a macaque has 17 times more sex-cell-producing glandular tissue than a langur.

On the basis of skeletal proportions, Dr. Schultz adds further criteria for classification of the primates. In last year's report reference was made to his measurement of the vertebrae and length of spinal regions in 300 freshly killed specimens. These studies have been continued and are now in published form. He finds that all the higher primates differ from the lower catarrhines in possessing relatively longer cervical and sacral regions and also a slightly longer thoracic region, but relatively much shorter lumbar and caudal regions. Man differs from the great apes in having the relatively longest cervical, thoracic, and lumbar regions. In his evolutionary trend he is thus the most progressive of the anthropoids in the first two regions and most retarded in the last. Speaking metaphorically, man thus hangs his socks on one part of the ancestral tree and his waistcoat on another.

An interesting sex difference found in man and all other primates studied is the characteristic of the male in having relatively slightly longer cervical

and thoracic regions and a relatively slightly shorter lumbar region than the female. The important task remains to determine how these lengths are modified by age, but this must await suitable material. It is to be noted that a change in the number of vertebrae of a spinal region does not imply a corresponding relative length of that region. As between different families there appears to be no correlation between these two factors, but within a species the reduction in number of the thoracolumbar vertebrae, for example, is accompanied by some decrease in relative length though not necessarily proportional to the loss of vertebrae. Much of the material upon which these measurements were made originated from the Asiatic Primate Expedition.

In an assemblage of data prepared for a recent symposium, Dr. C. G. Hartman has brought together evidence on the origin and affinities of man supplied by studies of monkeys and apes. Using his own observations on menstruation and other problems in the field of the physiology of reproduction, he finds new support for the phylogenetic seriation of monkey, chimpanzee, and man.

The quantity and character of the anthropoid material that is available for study in the various American collections has been surveyed and tabulated by Dr. A. H. Schultz in collaboration with Dr. W. M. Krogman, and a complete report has been made available for students in this field. The data for the report were obtained by a carefully prepared questionnaire, and the tabulators estimate that 95 per cent of the existing American specimens has been covered. The amount of such material will be realized when one sees that in these American repositories there are now 541 gorilla skulls, 263 complete skeletons of gibbon, 73 entire preserved bodies of chimpanzee, and 31 of orang-utan. There may have been some soiled hands along the way, but from here on this anthro-

poid material is destined to make many contributions to our understanding of comparative anatomy. One must not expect that the investigators are going to remain satisfied with this relatively abundant material. They will be calling for a still larger series of specimens.

PINEAL GLAND OF THE WHALE

A series of pineal glands obtained from adult humpback whales and preserved in alcohol has been studied microscopically by Dr. I. Gersh. It is because so little is known of this obscure organ that it becomes important to study it in a wide variety of forms, and Dr. Gersh has utilized his opportunity to make observations on this relatively rare material. The glands were collected from both male and female specimens, but no sex difference could be observed. Larger whales appeared to have larger glands. In a whale 14.3 m. long the pineal gland measured 18.0 mm. in its longest diameter. In the smallest whale of the group, 12.2 m. long, the gland had 14.0 mm. as its longest diameter. The human pineal gland is about 8.0 mm. in its longest diameter. On section the whale specimens present the general characteristics found in this gland in all mammals, at any rate in its parenchymatous organization. The chief peculiarity lies in the fact that the blood vessels, even including capillaries, are segregated in definite areas discrete from the parenchymatous cells and are only rarely seen in the glandular areas. The blood vessels bring to this gland the characteristic pattern they have in the other organs of the whale. They consist of a layer of endothelial cells invested by a layer of connective tissue. The larger of these vascular areas are encircled by a few smooth muscle fibers.

PRINCIPLES OF GROSS ANATOMY

In the effort to share time with new fields of study now necessary for medical

training, the courses in anatomy, which heretofore often constituted as much as 25 per cent of the medical course, are undergoing sharp contraction. Partial adjustment has already been made. The student is no longer required to master the whole body of minutiae contained in the anatomical textbooks, but he is still expected to perform a considerable feat of memorizing, a circumstance not thoroughly satisfactory to him or to his teacher. It is clear that further adjustments are called for. In line with this need is the work of Professor A. Brazier Howell, who has analyzed the structure of the human body along lines that appear particularly suitable for the student of medicine. His presentation has been brought out in book form during this past year. In searching for the principles that underlie human structure, Mr. Howell has resorted largely to his extensive experience in comparative anatomy and has supplemented it with many phases of embryology where they clarify the problems. His general attitude toward anatomy is that of the phylogenist, and with this he combines a wide knowledge of comparative anatomy and experience in the dissecting room. If such an approach proves to have reality for the student, instead of matter to be memorized it should provide him with a sure working tool, and may force the large textbooks into the rôle of reference material—let us hope, permissible on examination tables. There has recently appeared in England another book (Le Gros Clark) of equal proportions, also introductory or explanatory of human anatomy, which is based on the micro-gross organization of the body. It is a presentation that is not exactly histology as we now know it, but histology as it concerns the gross anatomist. It starts with the elements and from them synthesizes the body. In other words, the student is shown the organization of cells into tissues, tissues into organs and

organ systems, and these into the integrated living individual. Such an approach also equips the student with an understanding of the body that rests on something more than the ability to memorize relatively meaningless names and tabulations. It is purely realistic and devoid of hypothesis. It, however, is intended as an introduction to anatomy and does not attempt to replace the standard anatomical handbook. Still other approaches are being talked of, and they all signify that a reformation is taking place in the presentation to the medical student of the structure of the human body. It remains to be seen if Professor Howell has arrived at the best solution.

PATHOLOGICAL CONDITIONS AMONG WILD APES

Further evidence has been obtained by Dr. A. H. Schultz showing that wild monkeys and apes in a state of nature have a greater incidence of pathological conditions than was supposed. Adding to what is already known regarding parasites, chronic arthritis, and diseases affecting dentition, Dr. Schultz has made a series of observations on healed fractures in wild adult gibbons. Among 118 animals there were 42, that is 36 per cent, with healed fractures. Twenty-six of them had one fracture each, and each of the remaining 16 skeletons had two to four fractures. The most frequent sites were the femur, humerus, and phalanges. It may be added that the same animals exhibited various developmental disturbances, notably polydactyly, brachydactyly, spina bifida occulta, agenesis of an entire limb or ribs, impacted and congenitally lacking teeth, and fusion of atlas with occipital bone. Apparently the circumstances that have been introduced by man in his advances in civilization have borne more than their proper share of blame for the occurrence of disease.

DEPARTMENT OF GENETICS

A. F. BLAKESLEE, DIRECTOR

The Department of Genetics has as its province the study of the forces effective in heredity and evolution broadly considered. It devotes attention to the detailed mechanisms involved in the transmission of characteristics from parent to offspring by means of chromosomes and their constituent genes. It utilizes external stimuli, such as heat, radiation, and chemical treatments, to induce chromosomal and gene mutations and relates these laboratory findings to evolution in nature. It is interested in the manner in which genes control the processes of growth and development, and for this reason carries on detailed studies on the endocrine glands and on uncontrolled growth of blood cells in mouse leukemia. Its experimental genetic studies form a necessary basis for its research in human heredity and development.

The work of the Department has developed in research groups. Thus there are groups of investigators studying the gene, chromosome behavior, the hormones of endocrine glands in relation to growth and reproduction, leukemia, anthropology, and human heredity. The work of the different groups is related through weekly staff meetings at which current investigations are reported and discussed from the different points of view represented within the Department. The Carnegie Institution is not primarily an educational institution. The Department, however, has had a distinct influence on genetic education entirely aside from the part which it has taken in scientific meetings, exhibitions, and published papers. An effective library, seminars in some of the groups, and a weekly

journal club at which visiting scientists occasionally speak, are generally recognized as educational opportunities of no small value to members of the Department. Most of our assistants after a short period of apprenticeship with one of the research groups have little difficulty in securing assistantships or fellowships for graduate study in one or another of the leading educational institutions. An enumeration of those who have used their assistantships in the Department as part of their preparation for a professional career in genetics or related biological fields would make an impressive list.

Temporary assistantships in the summer are especially in demand by students in universities and by teachers. Every year it is necessary to decline some offers of volunteer assistance, although a limited number of persons are accepted on what is practically a volunteer basis so far as salary is concerned. None, however, work in the Department except on appointment as bona fide assistants or established guest investigators. Collaborating guest investigators sometimes bring assistants with them. Altogether a considerable number of institutions are represented among the assistants and investigators who are working in the Department on temporary appointment. This present season, for example, the members of the summer group alone have received their training in the following institutions: University of Alabama, Alabama School of Medicine, Allegheny College, Baldwin-Wallace College, Barnard College, Brooklyn College, Brown University, California Institute of Technology, University of California, College

of Physicians and Surgeons of Columbia University, Columbia University, Connecticut College for Women, Denison University, Duke University, Eureka College, Goucher College, Harvard University, Hope College, Hunter College, State University of Iowa, Johns Hopkins University, University of Illinois, Indiana University, Massachusetts Institute of Technology, University of Michigan, Middlebury College, University of Minnesota, Mount Holyoke College, Muhlenberg College, University of Nevada, New York University, Radcliffe College, Seton Hall, Smith College, University of South Dakota, Stanford University, University of Virginia, Wesleyan University, University of Wisconsin, Yale School of Nursing.

During the past five years the following guest investigators have been in residence in the Department:

Banta, A. M., Brown University
 Bauer, Hans, Kaiser-Wilhelm Institut für Biologie, Berlin-Dahlem, Germany
 Bridges, C. B., Research Associate of Carnegie Institution at California Institute of Technology
 Brown, L. A., Transylvania College
 Buchholz, J. T., University of Illinois
 Carlson, J. Gordon, University of Alabama
 Cartledge, J. Lincoln, University of West Virginia
 Chesley, Paul, Columbia University
 Delbrück, Max, Kaiser-Wilhelm Institut für Chemie, Berlin-Dahlem, Germany
 Dobzhansky, Th., California Institute of Technology
 Dotti, Louis B., New York Medical College
 Ephrussi, Boris, Institute de Biologie Physico-Chimique, Paris, France
 Gustafsson, Åke, Institute for Genetic Research, Svalof, Sweden
 Hall, Ada R., Wellesley College
 Hill, Thomas J., Western Reserve University
 Hrubetz, Caroline M., College of Physicians and Surgeons, Columbia University
 Huskins, C. L., McGill University
 Kaalund-Jorgensen, Otto, Dr. Kreh's Laboratory, Aarhus, Denmark

Kamenoff, Ralph J., College of the City of New York
 Kaufmann, B. P., University of Alabama
 Koller, P. C., University of Edinburgh, Edinburgh, Scotland
 Leblond, C. P., Pasteur Institute, Paris, France
 Levan, Johan A., Sugarbeet Research Station, Hilleshög, Landskrona, Sweden
 Pollack, Abou, Mount Sinai Hospital, New York City
 Robertson, C. W., Eureka College
 Schrader, Franz, Columbia University
 Schrader, Sallie H. (Mrs.), Sarah Lawrence College
 Sinnott, E. W., Columbia University
 Slizynska, Helene, University of Cracow, Cracow, Poland
 Slizynski, B. M., University of Cracow, Cracow, Poland
 Speicher, Benjamin R., University of Maine
 Spencer, Warren P., College of Wooster
 Stern, Curt, University of Rochester
 Waddington, C. H., Cambridge University, Cambridge, England
 Wettstein, F. von, Kaiser-Wilhelm Institut für Biologie, Berlin-Dahlem, Germany
 Whiting, P. W., University of Pennsylvania
 Whittinghill, M., Bennington College

The techniques and points of view brought in from so wide a range of institutions have been of great value to the research programs of the Department.

The research of the Department is characterized by group attack upon problems rather than by individual investigations. Of the 46 papers from the Department listed in the bibliography of last year, 20 were joint papers by more than one author. Of 7 publications, one of the authors belonged primarily to another institution but had cooperated in the investigation to the mutual advantage of the organizations involved.

That the research groups in the Department are recognized as profitable places in which to invest funds with expectation of high yields in scientific dividends is shown by the grants in furtherance of their research which have come from sources outside of the Car-

negie Institution. Thus, a portion of the work of the group specializing in endocrinology is supported by grants from the Carnegie Corporation of New York and from the National Research Council. The group studying leukemia has a grant from the Carnegie Corporation in support of its investigations in cooperation with the College of Physicians and Surgeons, Columbia University. The Carnegie Corporation is also supporting the polyploidy program of the group studying chromosome behavior, and a guest investigator from another institution has a grant from the American Philosophical Society in support of cooperative studies with our chromosome group. The group investigating the gene has established a stock center and information service for *Drosophila* workers and has organized a cooperative study of the biology of *Drosophila*, the fly which has proved so fruitful an organism for genetic study. Both of these undertakings are supported by funds from the Rockefeller Foundation.

Progress has been made during the past year by all the research groups, as is shown by the individual reports which are submitted herewith.

Gene studies by the group working with *Drosophila* have been concerned primarily with the nature of induced changes and their distribution along the chromosomes. Dr. Demerec, by study of a specific region of the salivary chromosomes of *D. melanogaster*, has shown that changes may be stable and viable, or lethal, or unstable. Lethal changes associated with inversions and translocations are generally not deficiencies, whereas those not associated with such aberrations are mostly deficiencies. It is seen, therefore, that similar biological effects may be produced either by elimination of the gene or by its suppression. Suppression of the activity of the gene is brought about to a large

degree through change in its position. Heterochromatin is that portion of the salivary chromosome within the chromocenter in which the banding is indefinite and in which the number of genes which have been located is smaller than in the euchromatic region. Demerec finds that when breaks and reattachments occur in chromosomes the genes which are brought into proximity with heterochromatin often become unstable, resulting in somatic mottling with spots of tissue in which the gene has reverted to the normal allelomorph. Dr. Kaufmann, from study of over 600 induced breaks in the X-chromosome, finds there are certain regions in which breaks are much more numerous. These regions he believes are heterochromatic, since the heterochromatin in the chromocentrum is especially liable to form breaks.

From a study of the nature of hybrid sterility by analysis of meiosis and post-meiotic development in eggs of hybrids between *D. miranda* and *D. pseudoobscura*, Dr. Kaufmann has concluded that sterility is genic and is probably attributable to a maternal effect of the hybrid chromosome complement on the egg cytoplasm prior to fertilization.

The group studying chromosomes have continued their investigation of polyploidy induced by colchicine. Dr. Bergner has found that this drug not only doubles chromosome number but causes elimination of chromosomes either without doubling to form $2n-1$ types or after doubling to form $4n-1$ and more complicated types with chromosome deficiencies. Miss Satina has found that frequently the epidermis may be $4n$ and the remaining tissue $2n$ or vice versa. In such periclinal chimeras it is possible to label the different tissues and thus to establish the constancy of one at least of the embryonic layers and to show that the outer layer may form a not inconsiderable part of the leaf and floral parts. Dr. Warmke has investigated the effects

of doubling the chromosomes of dioecious plants. In *Melandrium dioicum* the Y-chromosome carries male-determining elements. Contrary to the opinion of certain zoologists that polyploidy can be of no evolutionary significance, we have established a 4n dioecious race of this species in which males and females are in approximately equal numbers.

The group in endocrinology has concentrated its attention upon the secretions of the anterior pituitary. This gland is known to exercise extensive regulatory powers in embryo and adult, but the number of hormones which it produces and the manner in which they function are mostly unknown. Dr. Riddle and his associates report improvements in methods of assay, more complete separation of the different anterior pituitary hormones, and a better understanding of the specific responses which they induce, as well as the interaction of other hormones or chemical agents. Precipitation with copper hydroxide was found to give a fairly effective separation of gonadotropin and thyrotropin in extracts of hog pituitaries but not of cattle pituitaries. The volume of material injected in the local crop-sac assay was found to be a major factor in the response. A given quantity of prolactin in 0.5 cc., for example, gave practically the same result as four times this quantity in 0.05 cc. Estrogenic hormone given simultaneously with prolactin has been known to decrease the response of the crop-sacs to prolactin. Bates, Riddle, and Lahr have found that the estrogenic hormone induces partial starvation, and thus its apparent antagonism to prolactin is seen to be an indirect rather than a direct hormonal effect.

The pituitary gland is known to produce several kinds of hormones, and some have believed they have isolated a special growth hormone. Schooley and Riddle have studied the action of two so-called growth hormone preparations

supplied by others. Both these preparations they found had a considerable content of prolactin, to which they attribute the growth-promoting effect of these preparations.

Riddle and Senum have found that in pigeons and rabbits pituitary extract may induce a 50-fold increase in the blood fat. A similar increase in blood fat may be induced by estrogen. They conclude that the increase in blood fat which takes place during ovulation is due to the large amounts of estrogen released during that period.

The group working on mouse leukemia have given major emphasis to the analysis of induced resistance from both the chemical (Bovarnick) and biological (MacDowell and Potter) sides. They have accumulated a considerable body of consistent evidence which indicates that whatever chemical substance is responsible for resistance to leukemia is not separable from cells. These cells, however, need not be alive. Their outstanding discovery of the year has been that resistance to certain transplanted living leukemic cells can be induced by means of leukemic tissue which has been subjected to boiling heat. This result is in contradiction to the widely accepted conclusion that any resistance to a mammalian neoplasm depends upon the action of living cells.

Another important discovery in this group is that a condition which cannot be distinguished histologically from leukemia may be induced as a result of treatment with trypan blue. It lacks the physiological characteristics of malignant growth, however, in that progressive growth fails to take place both in the treated individual and in other animals of the same genetic constitution to which the abnormal tissue is transferred. The response seems to depend upon a certain genetic constitution, since it has been found in mice of only one of three strains tested. The induction of these

"leukemoid" cells without malignant properties may have general significance in accounting for some of the conflicting interpretations of the nature of human leukemia, as well as contributing to the conception of mammalian tumors as depending upon relatively slight deviations in normal processes.

Dr. Steggerda with assistants and collaborators has been studying the comparative anthropology of three more or less distinct ethnic groups: American Indians, Negroes, and whites. About 60 measurements were made on 100 Negro girls from Tuskegee Institute to compare with measurements of white girls in the same age groups from Smith College. The Negro girls average greater in shoulder and pelvic breadth and in chest girth, and their appendages are longer, but their sitting height is less than the same dimension of the white girls. This study, like other anthropometric studies of the Negro race, shows the Negroes to be more dolichocephalic than the white girls, their heads being longer and narrower. Their noses are broader and their ears more circular, as is seen by the figures for the aural index. Dynamometer readings on children show that the two Indian groups, Maya and Navajo, have a lower hand grip than the whites and Negroes. It is commonly believed that Navajo Indians are brachycephalic because as infants they are put on a cradleboard. By measurements of children who have never used a cradleboard in comparison with those who have, Steggerda has shown that though use of the cradleboard appears to have an influence in shortening the skull, it is not entirely responsible for the short heads which are characteristic of the Navajo Indians.

A study of the food used by the Navajos in comparison with the food of the Maya Indians has been made by Steggerda in cooperation with Dr. Carpenter

of the Nutrition Laboratory. The energy content of the different foods was relatively constant, about 4 calories per gram of air-dry matter. Maize is the chief food of the Maya, while mutton is the chief food of the Navajos.

Dr. Laughlin has completed a report on a survey of the human resources of Connecticut. The work has been a joint research of the State of Connecticut and the Record Office of our Department. In purpose and form this survey is comparable with surveys of other natural resources which many states have undertaken in other specific fields such as agriculture, wild life, minerals, etc. The present experiment is meant to pave the way for a new type of state survey which individual states can follow and perfect. The report consists of five parts: (1) "Family-stock betterment in Connecticut"; (2) "Handicapped families"; (3) "Laws of Connecticut"; (4) "Portfolio of fifteen charts"; and (5) "Portfolio of three hundred forty-six tables"—a total of 282 pages, 23 charts, and 346 tables.

For some years Dr. Laughlin has been engaged in statistical analysis of the racing behavior and ancestral relations of the thoroughbred horse. This investigation is finished or in process of completion. Volume I, "The measure of racing capacity," which gives a general analysis, is in course of completion. Volume Ia, "The 'Black book,'" the manual which lists formulae and values for computing quality of performance, is completed. Volume II, "The inheritance of racing capacity in the thoroughbred horse," which contains basic studies, is in course of completion. Volume IIa, "The 'Brown book,'" which contains tables for computing probability or expectation of specific racing capacity in the subject foal based on measured racing capacity in near blood kin, is completed.

CHROMOSOME INVESTIGATIONS

A. F. BLAKESLEE, A. G. AVERY, A. D. BERGNER, S. SATINA, H. E. WARMKE,
J. T. BUCHHOLZ, M. E. CONKLIN, AND E. W. SINNOTT

Our report last year was taken up with a discussion of the remarkable effects of the old gout remedy, colchicine, upon the chromosome mechanism in plants. By its use we found it possible to induce doubling of chromosome number and thus to establish tetraploid races in a wide range of plants. During the past year the use of colchicine has been extensively tested also by investigators outside our group. There now seems little doubt that colchicine is of wide application and that through its use new forms of plants of economic importance may be developed. Our prime interest in colchicine, however, is in its use as a new tool of research in major problems of genetics and evolution. Now that we can control doubling of chromosome number, it is possible to establish series of "polyploid" types (such as the $1n$, $2n$, $3n$, and $4n$ types secured in *Datura stramonium*) in which the chromosomes are in multiples of a basal number, and in such series it should be possible to establish laws regarding the effects of quantitative changes in chromosome material that will be of general application.

SUSCEPTIBILITY OF DIFFERENT PLANTS TO COLCHICINE TREATMENT

There has been found considerable difference in susceptibility of different species of flowering plants to colchicine even within the genus *Datura*, in which we have doubled chromosome numbers in the ten herbaceous species. The monocots as a group seem difficult to treat, in part perhaps because the growing point is often protected from the treatment by sheathing leaves. The plant *Colchicum autumnale* is the source of the alkaloid colchicine, the corm containing as much as 0.4 per cent by dry weight. The

Colchicum plant is not affected by the colchicine in its own cells, nor is any swelling of roots or doubling of chromosomes evident when the roots are immersed in strong concentrations of the alkaloid colchicine. It is like a snake which is immune to its own venom. Dr. Conklin has been unsuccessful in attempts to extract an "anticolchicine" from the corm which would inhibit the action of colchicine on other plants. It is possible that the immunity of the chromosomes of this plant to its own alkaloid may be tied up in some way in the nature of the species protoplasm.

As pointed out earlier, the fungi as a group appear immune to colchicine. Although the drug, except in dilute concentrations, is toxic to higher plants, the fungi have been found to tolerate relatively high concentrations. Dr. Conklin has found that some of the filamentous fungi and one at least of the bacteria thrive on colchicine and utilize it as a source of nitrogen in controlled cultures.

INDUCED CHROMOSOME DEFICIENCIES

The action of colchicine is not confined to doubling the number of chromosomes. It may induce the elimination of individual chromosomes as well. Last season, from over two thousand plants in the field which had grown from colchicine-treated seeds, a number of branches were selected as possible off-types and kept growing as grafts for detailed cytological study. Of these, Dr. Bergner has made cytological determinations of the chromosomal condition in 223, as shown in the table on page 182. There were 7 cases of the elimination of a single chromosome to produce $2n-1$ sectors. Such sectors have been extremely rare in untreated cultures, and in the present

case were undoubtedly induced by the treatment. It is uncertain whether any of the $2n+1$ types listed in the table were induced by the treatment, since nearly 0.2 per cent such types are expected as spontaneous mutations. It will be noted that elimination of single chromosomes after doubling is relatively common to give $4n-1$, $4n-1-1$, and $4n$ types which have lost a larger number of individual chromosomes. In the $4n-2$

From the types already discussed and the more complicated types listed in the table, it will be seen that treatment with colchicine is a means of securing a considerable number of new chromosomal types which are unbalanced by the loss of individual chromosomes.

PERICLINAL CHIMERAS

In determining the number of chromosomes it has been customary to count

CHROMOSOME RECORD OF 223 SELECTED PLANTS OF *DATURA STRAMONIUM*

Chromosome number	Total	Count only	First metaphase	Chromosomal type
23.....	7	1	6	$2n-1$
24.....	61	7	54	$2n$
25.....	6	.....	6	$2n+1$
26.....	1	.....	1	$2n+1+1$
42.....	2	.....	1	$4n-1-1-1-1-1-1$
43.....	2	1	1	$4n-2-2-1-1$
44.....	7	2	4	$4n-2-1-1-1$
45.....	8	.....	1	$4n-2-2$
45 + frag.....	1	.....	2	$4n-1-1-1$
46.....	28	9	6	$4n-2-1$
47.....	32	11	1	$4n-2-1 + \text{frag.}$
47 + frag.....	1	.....	7	$4n-1-1$
48.....	58	18	12	$4n-2$
49.....	2	1	21	$4n-1$
50.....	1	1	1	$4n-1 + \text{frag.}$
56.....	1	1	40	$4n$
57.....	1	1	1	$4n+1$
67.....	1	1		
89.....	1	1		
96.....	2	2		

types, in which 2 chromosomes are missing in one of the 12 sets of 4, the doubling of chromosome number has apparently taken place after a $2n-1$ cell has been formed by dropping out a single chromosome. It will be noted that of the 46 chromosome sectors, the $4n-2$ types, in which the two chromosomes have been eliminated from the same set, are nearly twice as frequent as the $4n-1-1$ types, in which a single chromosome has been lost from each of two different sets.

them in microscopic preparations of pollen-mother cells. A tetraploid ($4n$) sector in which the chromosome number has been doubled may be most readily distinguished from a normal diploid ($2n$) by the larger size of its pollen grains. These two methods give information regarding only the single subepidermal layer from which the pollen is derived. The fact that many of the off-type sectors on plants of *Datura* discussed in the previous paragraph gave counts of 24

($2n$) and 48 ($4n$) led us to suspect they were periclinal chimeras in which the outer layers are different from the inner tissue. By sectioning young buds Miss Satina has proved periclinal chimeras in a considerable number of cases, as shown in the accompanying table. In animals

TYPES OF PERICLINAL CHIMERAS FOUND IN
DATURA

Dermatogen	Periblem	Plerome	Number of plants
$2n$	$4n$	$4n$	1
$2n$	$2n$	$4n$	1
$4n$	$2n$	$2n$	19
$4n$	26 chr.	26 chr.	1
$8n$	$2n$	$2n$	2
$8n$	$4n$	$4n$	1
$4n$ - $8n$, mixed tissue	$2n$	$2n$	5

there are currently believed to be three germinal layers, ectoderm, mesoderm, and endoderm, which make definite contributions to the adult organs. Similarly, in the growing points of plants there are three layers distinguished which are believed to play definite rôles in the development of the shoot. The dermatogen is believed to give rise to the epidermis, the plerome to the central cylinder, and the periblem to the intermediate tissue. Our investigations seem to confirm the reality of at least the dermatogen, but to show that its contribution is not confined to the epidermis. When the dermatogen is $4n$ and the rest of the tissue is $2n$, this layer can be followed by the $4n$ number of its chromosomes in the relatively frequent cell divisions in young buds. An $8n$ dermatogen may be readily distinguished from the remaining $2n$ tissue by the enormous size of its cells alone. By such tagged cells, Miss Satina is finding that the dermatogen contributes a definite and considerable part to the internal tissue of the sepals, petals, anthers, and pistils.

SEX MECHANISM IN POLYPOIDS OF MELANDRIUM

The discovery of the colchicine technique has given us an opportunity to study the effect of doubling chromosome number upon the sex expression in dioecious plants. A number of dioecious species have had their chromosomes doubled by colchicine treatment, but most progress has been made in the study of *Melandrium*, in which the sex chromosomes are readily distinguished from the autosomes by their larger size. The $2n$ female has two large X-chromosomes, the $2n$ male has a large X- and a larger Y-chromosome. In *Drosophila* the Y-chromosome plays no rôle in sex determination. Warmke finds that in *Melandrium* the Y carries male-determining elements, since a plant with the formula $4A$ (autosomes) + XXXY is male and a plant with the constitution $4A$ + XXX is female. The opinion has been expressed that doubling chromosomes could not be a factor in the evolution of dioecious forms. Warmke's findings indicate that this conclusion is not warranted. In tetraploid *Melandrium* the tendency is to form XXXX females and XXXY males and to establish a $4n$ race with both males and females in adequate numbers to perpetuate the dioecious race. Of 130 plants which have so far flowered from the cross XXXX female by XXXY male, 62 have been male and 68 female.

FRUIT SHAPE IN CUCURBITA

The most striking result following the induction of polyploidy in cucurbits, in the cooperative studies undertaken with Dr. Sinnott of Columbia, is the change in fruit shape. In all the pure lines studied, the races which were known to be (at least approximately) tetraploid were found to have fruits markedly wider (equatorial dimension) than those of the diploids, and in most cases shorter,

as well. Thus the "Club" race of *Lagenaria vulgaris*, which in diploid phase has a fruit about 100 cm. long by 10 cm. wide, in tetraploid phase has one about 60 cm. long and 20 cm. wide, entirely different in appearance. Where there is a "neck" or basal extension, as in the "Bottle" type of *Lagenaria* or the "Necked" type of *Cucurbita Pepo*, this extension is shortened more than the rest of the fruit, with the result that the neck of the tetraploid is "pulled in" and the fruit is more rounded than the diploid.

That this general change in fruit shape is not a chance result but is due in some way to the induction of tetraploidy is indicated by the fact that it occurred in twelve different inbred lines. The tetraploids have not been counted exactly as to chromosome number, but their $4n$ condition is strongly indicated by the fact that the chromosome number is essentially double that of the diploid and that the pollen grains have twice the diploid volume. This latter character is the one which has been chiefly used in recognizing the tetraploids.

As to why tetraploidy should cause this change in shape, there seems no obvious answer. The tetraploid plants, as was to be expected, have somewhat stouter stems and thicker leaf blades. The fruits at maturity, however, are in most of the lines not greatly, if at all, larger than those of the diploids. The effect of size upon shape is therefore not involved. The shape difference appears very early, at about the time the ovary primordium is well organized (at a volume of 1 to 5 cu. mm.), and is thus evidently due to some early operative genetic mechanism and not to changes in later development. In every case, the cell volume of the tetraploid, as was to be expected, is about double that of the diploid, and it seems probable that this increase in cell volume in some way alters the developmental mechanism at a very early stage.

Even though differences between $2n$ and $4n$ types are evident very early, there are further differences which become manifest during development. If the cellular behavior of the two types is compared, it is found that the initial difference in cell volume, evident in the earliest primordia at the meristem, persists throughout. In the few lines for which it has been possible to make a complete developmental analysis, the cells of the tetraploid keep on dividing to a larger cell size than in the diploid, thus suggesting some physiological difference between the two types. After division ceases the cells also expand to a larger size, which is approximately twice that of the diploids. These differences, like those concerned with fruit shape, are presumably related to the doubled chromosome number; but how this doubling, unaccompanied by any changes in individual chromosomes or genes, can cause the developmental difference between tetraploids and diploids, is a very difficult but important problem, involving both genetics and development.

TETRAPLOID FLOWERS NOT ALWAYS LARGER

The peculiarity of tetraploid ($4n$) plants with doubled chromosome number that is of most interest to plant lovers is the increased size of the flowers in comparison with those of normal $2n$ races from which they have been derived. The effect upon flower size of doubling the chromosome number is found to differ with different species. Usually the tetraploids have distinctly larger flowers. In two species of *Portulaca* (*P. grandiflora* and *P. parana*), however, $2n$ may be as large as $4n$ flowers. This fact should make one cautious in generalizing on characteristics of tetraploids before adequate material has been studied. So far as we have investigated, we have found no exception as yet to the following char-

acteristics of tetraploids in comparison with diploids: larger pollen grains and seeds, larger guard cells in epidermis, thicker and darker leaves, and stouter fruits.

ATTEMPTS TO DECREASE CHROMOSOME NUMBER

Now that a ready method is at hand whereby the number of chromosomes may be doubled, we are seeking for some means by which the number may be reduced to half. The problem would appear to be solved if a method of inducing parthenogenesis of unfertilized eggs could be discovered. That such eggs are capable of developing without fertilization is indicated by the spontaneous occurrence during the last twenty years of 220 haploids ($1n$) in *Datura* from $2n$ or modified $2n$ parents. The unfertilized $2n$ eggs of tetraploids ($4n$) would seem most amenable to treatment for several reasons. The resulting offspring would be normal diploids ($2n$). Furthermore, such $2n$ eggs can be induced to form embryos without fertilization by means of the cross $4n \times 2n$. Including the tests made last year, we have had from this cross 21 triploids ($3n$) due to actual fertilization

and 18 diploids ($2n$) due to parthenogenesis. Since the cross is a difficult one to make and at best results in very few offspring, it has only limited value in getting diploids from tetraploids, and the crossing method is not usable in halving the chromosome number of diploids ($2n$). Evidence is at hand which indicates that at least two different stimuli may be necessary for parthenogenesis in plants. Dr. Buchholz has found that pollen which has been heavily treated with X-rays will produce pollen tubes which grow through the style but which cannot take part in embryo formation. The growth of such pollen tubes, however, causes the ovary to enlarge although no seeds are formed. Warmke has found that treatment with indol-butyric acid has an effect similar to the growth of tubes from radiated pollen. Now that we have found a chemical stimulus that will hold the capsule, we have apparently narrowed the problem to a search for a second stimulus which will force the unfertilized eggs in such capsules to develop into viable embryos. As pointed out earlier, ability to halve the chromosome number at will would be of considerable practical as well as theoretical value.

THE GENE

M. DEMEREC, B. P. KAUFMANN, AND EILEEN SUTTON

NATURE OF CHANGES INDUCED BY X-RAYS

During the past seven years material has been accumulated and cytogenetic study has been made of changes induced by X-rays in the white-Notch region of the X-chromosome of *Drosophila melanogaster*. This experiment is now completed and the final report is being prepared. More than one hundred changes induced in the sperm of treated males have been studied. The work was carried on by M. Demerec in cooperation with Margaret E. Hoover, Eileen Sutton, and Eunice White. A preliminary report de-

scribing the experimental set-up and some of the conclusions was published in last year's report.

Changes found in the white-Notch region fall into three well-defined groups:

1. Stable viable types. In this group 28 cases were studied, none of which showed any chromosomal rearrangements such as translocations or inversions. Eleven of these were examined carefully, band by band, for small inversions, deficiencies, and differences in band intensities. None has been observed. It seems probable that this

group represents gene mutations, namely, changes due to chemical alterations in the gene molecule of the white locus.

2. Lethal types. Forty-four cases were found in this group, which fall into two classes: (a) types without chromosomal rearrangements (inversions and translocations), and (b) those with chromosomal rearrangements. In the first class, among 33 cases, 30 showed deficiencies of from 1 to 50 bands, while 3 cases showed no cytologically detectable deficiencies. On the other hand, among the 11 cases of class (b), only one deficiency was observed, 10 cases having all bands present. These data show that when lethal changes are not associated with chromosomal rearrangements, they are, in the great majority of cases, deficiencies, and when associated with rearrangements, they are not deficiencies. In both cases, whether a deficiency is present or not, the biological effect is similar; both are lethal and cell-lethal, and show similar phenotypes. In cases where deficiencies are present, the effect is produced by the elimination of the gene, and in cases where no deficiencies are observed it appears probable that the effect is produced by the suppression of gene activity. The relation between non-deficient types and chromosomal rearrangement types with the break adjacent to the changed region indicates that the incidence of such suppression is much higher when the locus is taken out of its normal sequence and attached to some other region of the chromosome. In other words, the suppression of the activity of the gene is brought about to a large degree through the change in its position. In these cases the chemical constitution of the gene may not be affected at all, but the activity of the gene may be changed or suppressed by the change in its immediate environment.

3. Unstable types, showing mottling due to the combination of mutant and

wild-type tissues. Of the region studied, all loci, namely, white, roughest, facet, diminutive, echinus, and bifid, may show mottling. Of 30 cases available in this group, all are chromosomal rearrangements with one break in this region and the other break in the heterochromatin, which is, therefore, responsible for the instability, as has been pointed out by J. Schultz. The finding of two stable rearrangements involving the heterochromatin indicates that the presence of the heterochromatin does not always induce unstable changes in that region. Evidence is available showing that the heterochromatin of all chromosome limbs may induce mottling, that the heterochromatin of the X is less effective than the heterochromatin of the autosomes, and that the potency in inducing mottling differs in various sectors of the heterochromatin.

It is known that high temperature increases the frequency of wild-type spots. Experiments showed that the spotting may be influenced even when the change in temperature is made in the prepupal period. For example, if larvae are raised at a low temperature until shortly before pupation and then are transferred to a high temperature, the flies produced will have light eyes with many small red spots. Control tests indicate that these spots were induced by high temperature in the stage immediately preceding pupation. This shows that dark spots develop from light tissues, and, therefore, that the changes producing mottling are changes from the mutant to the wild-type. This eliminates the possibility that they are caused by deficiencies originating during the development of the fly. The more probable explanation of the mottling seems to be that the genes of this region of the chromosome, when brought into proximity with the heterochromatin, frequently become unstable. This instability may be due either to a reversible

chemical change in the gene or to a reversible suppression in the activity of the gene. This experiment brought out a striking difference between the effect of heterochromatin and the effect of euchromatin on the loci near the attachment point. The data show that heterochromatin induces unstable changes, the effect usually spreading to several adjacent genes which may be located some distance from the point of reattachment. One case is known in which the instability affected a section including at least 35 bands. On the other hand, in rearrangements involving euchromatin, only one locus very near the break is affected, and all changes caused by such rearrangements are stable and lethal.

Additional data obtained during the past year are in full agreement with the conclusions outlined in last year's report regarding the origin of deficiencies. Up to now 33 cytologically detectable deficiencies have been studied. In the group involving 6 to 50 bands various lengths were represented with an approximately equal frequency, as would be expected on the assumption that such deficiencies were produced by two breaks caused by two independent events and the loss of a piece of the chromosome between these two breaks. However, small 1- to 5-band deficiencies constitute about one-half of the total deficiencies found. This high frequency indicates that their origin has not been caused by two independent breaks. It seems very probable that generally such small deficiencies have been induced by one event producing either two interdependent breaks or a chemical change.

This work also brought out ample evidence to show the intimate relation between the various parts of a chromosome. The evidence suggests that the activity of a gene depends greatly on its immediate environment. The activity of a gene may be changed or suppressed by chromosomal rearrangements through

which a foreign section of a chromosome is brought into contact with the gene. It is evident that various regions of a chromosome differ in the effect they produce. As shown by Kaufmann and Demerec (1937), the breaks in the euchromatic and the heterochromatic regions occur with an approximately equal frequency per length of the chromonemata. Since in *Drosophila* euchromatin is at least three and a half times as long as heterochromatin, it is to be expected that rearrangements involving the white-Notch section and a euchromatic region would be about three and a half times as frequent as rearrangements involving heterochromatin. In the material used in the study, however, rearrangements involving heterochromatin are much more frequent than those involving euchromatin. Thirty-two were found in the first group and only nine in the second. These rearrangements are detected by the phenotypic effect they produce, indicating that heterochromatin is much more effective than euchromatin in inducing changes in the white-Notch region. Because, however, the great majority of changes induced by heterochromatin are reversible and viable and those induced by euchromatin are stable and lethal, it may be said that in this particular region the heterochromatin produces a weaker effect than the euchromatin.

Cytogenetic study was completed by M. Demerec and Eileen Sutton of an X-ray-induced change in which a piece of the X-chromosome from 3B3·4 to 3D5·6 inclusive, carrying the loci white, roughest, facet, and diminutive, was inserted in an inverted position into the heterochromatin of 3L. A genetical analysis showed that white, roughest, and facet became unstable, producing mottled phenotypes, while diminutive changed to a stable mutant type. Cytological analysis indicates that none of the bands were lost in the transfer. Two types, a deficiency and a duplication, were iso-

lated from that original change. It is of interest to note that this duplication does not compensate for any of the lethals known in this region. Not only does this duplication not compensate for the lethal effect of the Notches which are single-line deficiencies, but it does not even compensate for the lethal effect of non-deficient Notches which are involved in the chromosomal rearrangements. This indicates that the transfer into the heterochromatin had suppressed the activity of the genes of this region of the chromosome to such an extent that they had become unable to make up for either the loss or the inactivation of their sister genes. Genetic tests indicate that the piece of the X-chromosome is inserted between the intumed (in) and peach (p^e) loci. The cytological study showing that the piece is inserted in the 3L limb indicates that the spindle fiber attachment of the third chromosome is located to the right of intumed (in) and not to the left, as shown on the present genetic maps.

STRUCTURE OF EUCHROMATIN AND HETEROCHROMATIN

A cytological study of rearrangements which brought euchromatic bands of the X-chromosome adjacent to a heterochromatic region was made by Eileen Sutton. The material was taken mostly from the X-ray experiments on the white-Notch region, and included the insertion in the heterochromatin of 3L described above. Intensive study of this and four other aberrations gave no evidence that the bands of the white-Notch region were affected in any way (lost, intensified, or changed in structure) by their change in position. In one inversion in X, however, in which bands in the "bulb" (2B) region were transferred to the heterochromatic region, the bands next to the left break were found to be darker than the corresponding bands in the normal X in

about one-third of the figures examined; but in connection with this, it should be noted that 2B is one of the regions claimed by Prokofyeva (1938) to be heterochromatic. In no case did heterochromatin seem to be affected by the proximity of euchromatic bands which are normally located some distance away. It would seem, therefore, that the different effects on euchromatic bands translocated to heterochromatic regions described by Schultz (Year Book No. 37 [1937-1938]) and Prokofyeva (1937) and the latter's reciprocal effect may be found in some cases, but are not of general occurrence.

DISTRIBUTION OF INDUCED BREAKS ALONG THE X-CHROMOSOME

A study by Bauer, Demerec, and Kaufmann of induced chromosomal rearrangements in *Drosophila melanogaster* was reported in the last Year Book. Problems arising from that study indicated the necessity for securing further data on break distribution. Accordingly, B. P. Kaufmann, with the cooperation of E. A. Bickell, Jr., has plotted the distribution of more than 600 additional breaks. Analysis was restricted to the X-chromosome because Bridges' 1938 map permitted accurate determination of breakage points within the limits of the lettered subdivisions. About 45 per cent of the breaks (287 out of 627) were in chromosomes carrying the delta-49 inversion, the remainder in chromosomes having the wild-type sequence. Break distribution in and adjacent to inversion points was studied as a measure of the frequency of reinversion.

Comparison of break distribution in the dl-49 and wild-type chromosomes shows no significant differences. In both cases many of the same sections conform closely to expected values, and others deviate sharply therefrom. The expected values have been determined from the

number of bands per subdivision. The numbers of observed breaks in subdivisions 4D, E, F and in 11E, F, 12A (the subdivisions closest to the limits of the inversion) were 1, 2, 4 and 1, 3, 0 respectively, as compared with expected values of 1.51, 0.65, 3.02 and 2.80, 1.72, 2.16. It is apparent that there are no constellations of breaks centering about the limits of the inversion. This finding, coupled with that of general similarity of break distribution in both types of chromosomes, points to the conclusion that the dl-49 sequence is not more fragile in its response to X-radiation than is the control. Accordingly the data may be considered as a whole.

The number of breaks which have been detected in the proximal heterochromatic region is about 23 per cent of the total for the X. If adjustment is made for undetected breaks associated with inversions or interchange restricted to heterochromatin, the percentage of breaks in the proximal heterochromatin reaches 28.4 per cent. This is somewhat short of the expected 33.3 per cent, but nevertheless does not exclude the possibility that break frequency is proportional to mitotic chromosome length.

Among the rearrangements involving two breaks, there were 50 inversions. As was shown by the study of Bauer, Demerec, and Kaufmann, inversions restricted to euchromatin conform in length closely to values to be expected on the assumption that two breaks occur at random, that is, independently of each other. In the present study, the number of euchromatic inversions of various lengths when compared with expected values gives a probability (P) of close to 0.7 when calculated by the χ^2 method.

The positions of 475 breaks have been determined within the so-called euchromatic divisions 1 to 19. When break frequencies are plotted against expected values, several significant departures

from randomness are apparent. The most striking differences between expected and observed frequencies were found in sections 11A, 12D, 12E, and 19E. Other subdivisions with a high break frequency that appears to fall outside the limits of chance distribution are 1F, 4E, 7B, 7C, 8B, 16E, 16F, and 19F.

The high break frequency of such regions as 11A, 12D, 12E, and 19E simulates that of the proximal heterochromatin and suggests that these intercalary subdivisions likewise contain heterochromatic material. In support of this interpretation there is the cytological evidence that these regions contain "reversed repeats" which in the salivary chromosomes show distorted and diagonal synapsis within the subdivision, or pairing between the bands of one of these regions and those of any of the others or the chromocenter. It seems therefore that the properties of heterochromatin may account for the irregularities of pairing in these intercalary subdivisions as well as for the high incidence of induced breakage occurring therein.

Some of the other regions with a high break frequency that seems to fall outside the limits of chance distribution appear cytologically to represent repeats (for example, 8B); others show no conspicuous repetition of banding. On the other hand, certain regions which appear cytologically to represent repeats, such as 2B and 3C, have not shown a high break frequency in the present experiments. With respect to the tip region, subdivisions 1A to 1F all show break numbers higher than expected values, but not deviating sharply therefrom, except for 1F. In order that such differences may be appraised more critically and that pronounced trends may be distinguished from chance deviation, this study on break distribution is being extended.

Evidence of the existence of interca-

lary heterochromatin in the X suggests that similar regions may be present along the limbs of the autosomes, as for example in the "loops" and "turn-back" of the left limb of the second chromosome. It seems possible that the production of mottling which may follow transfer of sensitive loci to distal autosomal regions may involve juxtaposition to such intercalary heterochromatin. Likewise, if higher break frequency occurs at certain levels along the chromosome, the possibility of inversion and reinversion between two such loci increases. In addition, the existence of intercalary heterochromatin may explain certain regional differences in distance as measured along the salivary chromosome between pairs of loci with similar crossing-over frequencies.

Analysis of the more than 4000 pairs of glands surveyed in this study has given additional information on the types of induced changes occurring following irradiation of sperm. Most of these types have been described elsewhere. In one case previously unreported, some of the nuclei of a pair of glands showed a duplication in the form of a "reversed repeat" for the distance from 5F to 15F. Other nuclei of this pair of glands were deficient for this section. Since slides are prepared from glands of F_1 larval descendants of irradiated fathers, it appears that the chromosome was longitudinally double at the time of irradiation, and that both of the strands of the paternal X-chromosome have been recovered.

REVERSION OF ROUGHEST

In connection with the problem of the frequency of reinversion and increased breakage at inversion points, Kaufmann has begun a study of induced changes from roughest³ to wild-type. Of 6797 F_1 females from irradiated fathers, 75 were phenotypically wild-type. The greater portion of these remain to be

tested cytologically, but already four changes have been detected. Two are reciprocal translocations between 2L and the X heterochromatin, one is a reciprocal translocation between 3R and the X heterochromatin, and one involves transfer of the nucleolus-organizing region from the X to 3L. Another series of 22 changes from roughest to wild-type was obtained in F_1 males. All these proved to be sterile, so that no cytological observations on salivary chromosomes could be obtained. Evidently reversion of roughest may be associated with different types of chromosomal rearrangements, probably involving in each case a break or breaks in the proximal heterochromatin of the X.

ABNORMAL DEVELOPMENT IN EGGS OF HYBRIDS

As has been shown by Dobzhansky and others, crosses between the Olympic 1 strain of *Drosophila miranda* and the Texas, race A, strain of *D. pseudoobscura* produce sterile hybrids. In an effort to determine whether this sterility is of the genic or the chromosomal type, Kaufmann studied meiosis and subsequent developmental stages in eggs of hybrids fertilized by sperm of one of the parental species. Most of the eggs furnished evidence that the meiotic divisions are carried to completion. Under such conditions some of the female pronuclei should carry a complete set of chromosomes of one of the parental species. Zygotes containing such pronuclei should possess potentialities for continued development, unless inhibited by the genetic constitution of the organism. Early evidence of abnormal development is the irregular distribution of chromosomes seen in some first cleavage mitoses. In those eggs in which the first few cleavage mitoses appear to proceed normally, multiplication and extreme proliferation of the polar

chromosomes may prevent normal subsequent development. The irregular distribution of chromosomes of cleavage and polar nuclei leads ultimately to the formation of a large number of scattered bits of chromatin or a smaller number of large chromatin masses. As a result, embryonic degeneration ensues within a few hours after fertilization. This analysis of meiosis and subsequent development indicates that sterility is of the genic type and is probably referable to a maternal effect of the hybrid chromosomes on the egg cytoplasm before fertilization.

EFFECT OF ULTRAVIOLET RADIATION

In cooperation with Alexander Hollaender of the Division of Industrial Hygiene of the National Institute of Health, Washington, D. C., M. Demerec, Edith Neidle, and M. O. Dermen are conducting a series of experiments to test the effect of the monochromatic ultraviolet radiation on hereditary changes. Preliminary experiments made in working out the technique and in determining the dosage show that lethal changes can be induced by treating the sperm with monochromatic radiation of either 2650 Å or 2950 Å.

EXPERIMENTAL LEUKEMIA

E. C. MacDOWELL, J. S. POTTER, M. BOVARNICK, M. N. RICHTER, M. J. TAYLOR,
E. N. WARD, T. LAANES, AND M. P. WINTERSTEINER

In pursuing the general program of systematic analysis of specific reproducible phenomena as an approach to the discovery of mechanisms of general significance, the cooperating groups in the Department of Genetics and the College of Physicians and Surgeons of Columbia University have focused attention upon the processes involved in the induction of resistance to leukemic cells.

RESISTANCE INDUCED BY HEAT-KILLED LEUKEMIC CELLS

As a part of the program devoted to the attempt to isolate antigenic substances as a clue to the nature of mechanisms of resistance, Dr. Bovarnick discovered that susceptible mice could be protected against lethal doses of leukemic cells of line I by a single treatment with these cells that had been heated to 45° to 47° C for 10 to 13 minutes. Of a total of 152 mice, 138 survived this treatment with heated cells and were tested in 3 to 20 days with lethal doses of unheated cells: 59 per cent of these mice survived the test dose that would otherwise have

killed every one. These results were confirmed at the Department of Genetics, using temperatures between 45.8° and 46.1° C, controlled within 0.05°, for 10 minutes and testing with the same lethal dose in 20 days; of a total of 119 mice, 117 survived the treatment with heated cells, and of these 83.7 per cent survived the lethal dose of unheated cells.

Although the heat treatment inactivated most of the leukemic cells, the occasional transmission of leukemia indicates that a few cells survived; the interval before death in these cases was as long as the interval given by the highest dilutions of untreated leukemic cells that are occasionally lethal. Since high dilutions of these cells that are not lethal induce resistance to subsequent lethal doses (Year Book No. 33 [1933-1934], p. 43), it is not necessary to assume that heat-inactivated cells have an antigenic effect as long as living cells are present. This interpretation was supported by three experiments (including 90 mice) in which slightly higher temperatures were used; in no case was

leukemia transmitted by the heated cells, and no mouse was protected against the lethal test dose.

Combined with the large body of published evidence indicating that living cells are necessary for antigenic action against any mammalian tumor, these results with heat seemed to offer small promise of a separation of the pathogenic and antigenic actions of leukemic cells. However, the possibility that the heat-inactivated cells had some antigenic effect was certainly not eliminated, and, although this was not clearly demonstrable, large doses of heated cells appeared to induce resistance more effectively than very small doses of unheated living cells. While this did not offer a lead for further analysis, the work of bacteriologists did offer a fruitful suggestion, in that certain bacteria are more strongly antigenic when suddenly subjected to high temperatures than when heated just enough to kill. Accordingly a series of experiments has been started using temperatures of 100° and somewhat lower. Since the probability of any result seemed very small, the test dose of living cells was reduced to $\frac{1}{8}$ that previously used, in order to detect a possible weak effect. This test dose is so small that controls occasionally survive; this means that the 100 per cent basis that has given unquestionable significance to small numbers in most of our work does not hold for these experiments. In spite of this, clear evidence was obtained of some antigenic action of leukemic cells that had been unquestionably killed by heat. In this series of experiments 225 mice have been treated with heat-killed leukemic cells; 47.0 per cent survived the reduced test dose, while 3.8 per cent of 184 controls survived.

These results raise many questions and open a new field: a new phenomenon to be analyzed and a new tool for studies on immunological differences between

different populations of leukemic cells and between leukemic and normal cells. Two immediate questions are being studied: Does the resistance resulting from heat-killed leukemic cells depend upon the preservation of the same molecular structures responsible for the antigenic effect of living cells, or is an entirely different mechanism of resistance called into operation? Is the protection due to the leukemic or to the normal properties of the heated cells?

Many other treatments have been tested by Dr. Bovarnick in an attempt to dissociate the malignant and immunizing properties of leukemic cells of line I, but the results in none of these experiments were fruitful. The treatments of leukemic cells included: hydraulic pressure, grinding, filtration, and eleven chemical agents—urethane, KCN, HgCl_2 , iodoacetic acid, normal sodium fluoride, saturated isotonic aqueous solution of 2,4-dinitrophenol, glycerine, iodine, hypertonic saline, histone, and salmine—as well as buffers between pH 3.9 and 8. Whenever the treatment was strong enough to destroy the malignant property, the immunizing power could not be demonstrated.

Similarly, various methods of extracting the material responsible for the resistance induced by normal tissue of strain StoLi have continued to give negative results in accord with a statement in last year's report. In this series have been used: freezing at -70 and -200°C , aerobically and anaerobically; desiccation under vacuum at icebox temperature; autolysis at various pH; grinding in various media; acetone, soluble, insoluble, and recombined fractions; formalin.

COBALT CYSTEINE

An attempt was made to repeat the experiments of Engelbreth-Holme claiming to demonstrate the transmission of mouse leukemia with acellular material

extracted in the presence of the highly reducing cobalt cysteine system. This author's procedures were followed as closely as possible with completely negative results. At the same time an experiment was set up to test the direct effect of cobalt cysteine upon mice otherwise untreated but naturally endowed with a tendency to develop spontaneous leukemia after middle age. Twenty mice, 6 to 8 weeks old, were injected intraperitoneally with an anaerobically prepared cobalt cysteine solution of the same concentration as used by Engelbreth-Holme; each mouse received 1 cc. at each of 8 injections spaced at intervals of 3 to 4 days. Of these 20 mice, 17 died with leukemia 26 to 38 days after the first injection. Of these 17, 4 were used successfully as donors, showing that the leukemia was transmissible.

Further experiments on the direct effect of cobalt cysteine, however, led to consistently negative results. These experiments included attempts to repeat exactly the conditions under which the above apparent induction of leukemia was accomplished, as well as variations in both number and size of dose and the use of both oxidized and reduced forms of the cobalt cysteine complex.

NONMALIGNANT LEUKEMOID REACTION

An attempt was made to determine whether the reticulo-endothelial system, through the production of antibodies, was active in the phenomena of resistance. Would blocking this system with trypan blue modify the induction of resistance? Although trypan blue has frequently been used to block the reticulo-endothelial system and the method and dosage of previous workers were followed, the primary purpose was defeated by the appearance of a pathological condition induced directly by this vital dye. This condition in gross autopsy and in microscopic sections could not be distinguished

in some cases from the lesions of leukemia (see fig. 1), and yet the physiological criteria that constitute the malignant characteristic of leukemia were lacking; that is, the aberrant growth within the individual was neither continuously progressive nor often lethal, and the abnormal tissue when transplanted into other mice of the same genetic constitution failed to grow. Clinically, the peripheral blood of the mice treated with trypan blue contained immature cell types and gave elevated white cell counts, but along with this indication of leukemia appeared surprising emaciation and loss of hair, with heavy incrustation of the skin.

Of three strains of mice tested, this condition appeared only in young mice of strain C58, the strain which carries genes conditioning the spontaneous occurrence of leukemia late in life. Thus the abnormal formation and growth of leukemoid cells appears to be a response in some manner related to true leukemia, but the significant fact is the separation of malignancy from abnormal cell formation and from the resulting lesions, which previously have been known only as manifestations of malignancy.

The leukemoid response to trypan blue is not merely an incomplete induction of leukemia; for besides the fact that death was caused in a few cases, the lesions were typically many times larger than the early lesions of true spontaneous leukemia, which readily transmit leukemia upon transplantation.

In previous reports evidence of the action of unknown extrinsic agents in the manifestation of leukemia has been presented, and the identity of such agents remains in question, although the first experiments with trypan blue seemed to show that this dye was acting as such an extrinsic factor. Subsequent experiments proved without doubt that the trypan-induced lesions are nonmalignant responses to a toxic agent.

It is becoming increasingly clear that in many studies on cancer, secondary effects due to the operation of normal processes under the abnormal conditions resulting from malignant growth have been credited to the primary malignant process itself. The above results go still farther in showing that even the primary histological phenomena supposedly due directly to a malignant process may appear without malignancy. Thus the similarity between cancerous and noncancerous conditions is still further emphasized (Year Book No. 36 [1936-1937], p. 54) and the conception is supported of mammalian tumors' depending primarily upon relatively slight deviations from normal processes.

Although the response to trypan blue depends upon highly controlled specific conditions, the discovery of the histological criteria of leukemia without malignancy may have general significance in accounting for some of the conflicting interpretations of the nature of human leukemia as well as for some of the confusion due to seeming cures.

PROCESS OF RESISTANCE

Histological descriptions of the process of resisting lethal doses of leukemic cells have been given in earlier reports for mice actively immunized and for mice protected by treatment with normal embryo tissue from strain StoLi. Similar studies based on serial sections of all organs have been made this year on mice passively immunized by treatment with liver from actively immunized mice; for comparison, litter mates protected by adult normal liver from strain StoLi and untreated controls were all inoculated, 3 days after the immunizing treatments, with the same dose of leukemic cells from the same cell suspension. Two mice a day from each of the treated groups were taken on alternate days from the 1st to the 9th after the leukemic

inoculation; two controls were taken daily for 5 days—controls die on the 6th day.

In both protected groups, leukemic cells survived and formed lesions during the first few days after inoculation. The division rate within these lesions was lower than in the controls and by the 5th day extensive degeneration of the lesions appeared in the same manner as described in actively immunized animals (Year Book No. 34 [1934-1935], p. 47); cytolysis occurred without intervention of host cells. After the debris was removed by active phagocytosis, reparative processes usually obliterated all evidence of previous damage. In some cases the positions of the lesions became occupied by host cells of different types. In the mice treated with immune liver, these persistent accumulations were of normal lymphoid cells which assumed the aspect of organized lymphoid tissue. In the mice treated with normal StoLi liver, these persistent accumulations were regularly myeloid. Contrary to expectation, this last point was the only difference between the mice protected by immune and normal liver; in the early series in which StoLi embryos were used (Year Book No. 35 [1935-1936], p. 47) no leukemic cells or lesions could be identified microscopically. The use of adult liver in place of embryo tissue does not account for this difference, for a new series with embryo tissue, studied for this purpose, gave the same result as the adult liver. Why this treatment with normal tissue should suppress all signs of leukemic cells at one period and at a later time permit the formation of temporary lesions cannot be answered directly, but the probability appears to be strong that an increase in the potency of the leukemic cell population is responsible. This year the interval before death and the blood count from a dose $\frac{1}{4}$ of the standard suspension of cells correspond to the interval and count from the standard

suspension of a few years previous. Another indication of change in the leukemic population called line I may be very closely connected with the appearance of leukemic lesions in the StoLi-treated mice; that is, the complete absence of superficial lymphosarcomata, which formerly appeared as a delayed result of protection by StoLi tissue against line I cells (Year Book No. 35 [1935-1936], p. 48). Since early lesions of leukemic cells are associated with both active and passive immunity induced by leukemic cells themselves, it seems probable that at the time StoLi treatment suppressed early lesions, active immunity was not developed and the

appearance of the lymphosarcomata under these conditions and *no others* was dependent upon this failure of active immunity.

Under the current conditions, three methods of inducing resistance show the same histological story, and in no case is the destruction of the leukemic lesions accomplished by an invasion of host cells. The "startling assumption" stated last year gains probability: that the normal genetic constitution of one strain has antigenic similarity to cells of another strain when they have become leukemic. If so, the deviation from normal that distinguishes leukemic cells cannot be very great.

ENDOCRINE STUDIES

O. RIDDLE, R. W. BATES, J. P. SCHOOLEY, T. SENUM, E. L. LAHR, R. A. MILLER,
AND G. C. SMITH

The anterior pituitary gland is known to exercise extensive regulatory powers in both the embryo and the adult, but the number of agents (hormones) it produces and employs for its far-reaching adjustments of structure and function, and the rules which govern these many adjustments, are mostly unknown. Present progress toward an understanding of the functions of this gland may rest upon improvements in methods of assay of its products, in the more complete separation of its hormones, in the positive identification of some specific response with one of its hormones, in a better understanding of the secondary products of pituitary hormone action, or in the recognition of the ability of other hormones or agents to affect the output or the effectiveness of any of the various pituitary hormones. Several such items of progress are reported by Dr. Riddle and his associates.

The investigations reported here deal almost wholly with one or another aspect of regulation by anterior pituitary hor-

mones and with hormones whose products are under the influence or control of the pituitary. The study of carbohydrate and fat metabolism was supported by a grant from the Committee on Research in Endocrinology, National Research Council. Several of these studies were greatly aided by a grant from the Carnegie Corporation of New York to the Carnegie Institution of Washington.

THE PREPARATION AND ASSAY OF PITUITARY HORMONES

New and better information concerning the products and functions of the anterior pituitary now seems more dependent upon reliable and extensive assays of every extract prepared and used than upon all else. These time-consuming assays—in groups of normal pigeons, rats, and chicks, with much use of hypophysectomized pigeons and young rabbits—are expensive but indispensable accompaniments of study of this subject. Through these assays we may increase the possibilities of prepar-

ing the pituitary hormones in pure form, and also give substance and value to whatever reactions are observed after injection of an extract or preparation derived from the pituitary. New methods of assay and further knowledge concerning the accuracy or reliability of current assay methods are therefore notable items of progress. The task of carrying out these assays was performed mainly by Mr. Ernest L. Lahr, Mr. Graham Erdwurm, and Mr. Louis Stillwell, Jr.

Quantitative tests for the thyroid-stimulating hormone (thyrotropin) of the anterior pituitary were both crude and expensive until the use of baby chicks for this purpose was introduced by Smelser a year ago. Using 500 chicks (cockerels) with this method of assay Bates and Riddle obtained satisfactory results on increase both in thyroid weight and in testis weight after five daily injections of one or another extract of anterior pituitary tissue. One of our own preparations (no. 630) which had been made free of prolactin was chosen as a reference standard because the minimal stimulating dose of this preparation was the same for both the thyroids and the testes. The relation between dosage and increase in weight of thyroids and testes was established with this preparation, and the amount of such increase in weight obtainable with 1 mg. of this preparation (no. 630) was designated as one unit of thyrotropin and one unit of gonadotropin.

With the aid of the standards thus obtained a comparison was made of amounts of thyrotropin and gonadotropin contained in several types of pituitary preparations. The potency, in units per milligram of both thyrotropin and gonadotropin in purified fractions isolated from pituitaries of hogs was found to be of the order of five times that of fractions obtained from pituitaries of cattle. Our standard preparation (no. 630) was as

potent as any other beef preparation studied. The ratio of gonadotropin to thyrotropin (G/T) in no. 630, which was made from beef pituitaries, is 1.0 by definition of the unit. The similarly derived ratio for unfractionated beef extracts is 0.2 to 0.5, and this ratio is maintained after separation of the prolactin, but in pork and sheep preparations the gonadotropin is relatively so much increased as to give ratios which approximate unity. When fractions that had been separated by precipitation with copper hydroxide were studied it was found that a marked separation of gonadotropin and thyrotropin was effected in the case of pork glands but not appreciably if at all in the case of beef glands. Two copper-soluble pork preparations gave ratios (G/T) of 25 and 50, respectively. The corresponding copper-insoluble preparations gave ratios of 0.9 and 0.15, respectively. In preparations made from pituitaries of cattle such a separation is not effected; our standard (no. 630) is a copper-soluble fraction, and no. 632 is its corresponding copper-insoluble fraction, but in both of these thyrotropin and gonadotropin are present in a ratio of 1.0.

The local crop-sac test of Lyons and Page is a micro-test for prolactin requiring only about one one-thousandth the quantity of material used in a "systemic" (intramuscular) test, but for general use it seems less satisfactory because it is based upon the threshold of stimulation and this is judged or quantitated by the eye. In the usual procedure small samples of graded concentrations of prolactin are injected intradermally over the crop-sac of a series of pigeons, the injections are repeated 24 hours later in the same site in the skin, and the crop-sacs are removed after 48 hours and examined with transmitted and reflected light for stimulation. Though one would suppose that the concentration of the solution injected is the main factor determining the threshold dosage, and that the volume

of fluid injected has significance only in determining the size of the area stimulated, Bates and Riddle have shown that the *volume* injected is a major factor. A series of tests was made in which the same quantity of prolactin was held in 0.05 cc. and in 0.5 cc. and these volumes injected over the right and left crop-sacs, respectively; in another series of tests this order of the injections was reversed, that is, the larger volume was injected over the right side. The results of the two series agreed well in showing that a specified quantity of prolactin in 0.5 cc. gave practically the same result as four times that quantity of prolactin in a volume of 0.05 cc. In terms of concentration this represents a 40-fold difference; and in these tests the visual judgment of threshold stimulation was checked by histological examination after colchicine technique.

Careful use of the local crop test for prolactin gives it practical value in connection with clinical studies which require information concerning the concentration of prolactin in blood, urine, and certain tissue or organ extracts. In addition to the large source of error noted above, our experience indicates that the injection of urinary preparations over the crop-sacs exerts toxic or irritation effects on neighboring tissues, including the crop-sac tissue, which simulate the response to prolactin and thus give questionable or misleading results. Some organic dyes such as azocarmine and Sudan black in aqueous solution also cause similar necrotic changes which, with the aid of colchicine technique, were shown by Mr. Lahr to involve a marked proliferation of crop-sac tissue.

FACTORS AFFECTING THE RESPONSE TO PROLACTIN

We noted last year that, confirming Folley and White, large doses of female sex (estrogenic) hormones markedly in-

hibit the response of the crop-sacs to prolactin. During the present year Bates, Riddle, and Lahr have learned the essentials of the mechanism by which that inhibition—which in terms of units may reach 75 to 85 per cent—is accomplished. It was found that the effective doses of estrogen notably reduce appetite and food intake and also markedly increase the rate of water excretion by the kidneys in the treated pigeons. These observations next led to measurements of effects of fasting and of diuresis on the crop-sac response to prolactin when these factors were not complicated by other hormone administration. Complete fasting during the period of the tests (4 days) was alone capable of inhibiting the crop-sac response to the extent of 50 per cent. When the rate of urine excretion was doubled during this 4-day period by a drug (theobromine), the crop-sac response to prolactin was inhibited to the extent of 40 per cent. Much though perhaps not all of what seemed to be an antagonistic action of female sex hormone and prolactin is thus found to be an indirect result of a reduced food consumption and of (presumably) a more rapid loss of prolactin through the kidney as an incident of diuresis.

Several years ago Riddle and Tange noted that estrogenic hormone results in some loss of body weight in pigeons, and more recently we and others have noted that estrogens even prevent the gains in body weight which prolactin regularly induces in these birds. The results just noted above therefore also serve to clarify this hitherto unexplained effect of estrogens on the body weight of pigeons.

A survey of the importance of race or strain in the assay of prolactin has been completed and published by Bates, Riddle, and Lahr. It is found that different races and strains of doves and pigeons may differ markedly in the response (in-

creased weight) of their crop-sacs to prolactin when this hormone is injected either intramuscularly or subcutaneously. When the crop-sac responses obtained are expressed in terms of prolactin units, an extreme variation of 5-fold was found among 6 races of pigeons and of 8-fold among 14 strains of doves. These variations were still more extreme when high dosage of prolactin was employed. It therefore follows that when any race of pigeons is used for quantitative assay of prolactin by the weight method, it is first necessary to determine the useful range over which crop-sac weight increases with dosage, and thereafter to establish a racial correction factor with the aid of a standard prolactin preparation.

The question of the source of these large differences in response of the crop-sacs of different races is not negligible, and its answer involves at least three possibilities. The difference may rest solely upon an inherent difference in the responding (crop-sac) tissue, and in that case an important and hitherto little-recognized type of genetic difference in sensitivity to a hormone is involved. The hereditary difference may relate, however, solely to the factors or mechanisms that determine the concentration and persistence in the blood stream of the injected hormone; and such mechanisms, particularly those controlling the rates of absorption and elimination, may be considered as general metabolic mechanisms. A third possibility is that the observed difference rests both upon the responding tissue and upon such metabolic mechanisms. In any case, genetic change involving increased or decreased response to a hormone may not only have (in the wild state) a survival value but also become the proximate source of obvious somatic (phenotypic) change of race or type.

PITUITARY INFLUENCE ON SIZE OF BODY AND VISCERA

A special relation of the anterior pituitary to bodily growth in higher animals is firmly established, but the specific way or ways in which this influence on growth is exercised seems in much doubt. From more than one point of view the solution of this problem is of major importance in endocrinology and biology. Previous studies on the pigeon (and dwarf mouse) in this laboratory have led to the view that more than one now known anterior pituitary hormone plays a part in bodily growth and that the rôle of any one of these hormones may be greater or less in one species than in another. This subject has been actively studied during the past year, though most of the results have not yet been subjected to the full analysis which would justify their inclusion in this report. Our studies were made chiefly on three types of animals from which the pituitary glands were removed: Carneau pigeons 12 days old and 44 days old, and Brown Leghorn chicks 37 days old. In all groups the effects of hypophysectomy on body and organ weights were studied; in the two types of pigeon, which differ greatly in the stage of bodily growth attained at the time of operation, studies were made on the value, at the two stages of life, of different pituitary hormones in replacement therapy.

We have earlier reported that hypophysectomy in Carneau pigeons aged 44 days produces within 10 days very profound weight loss in several visceral organs and in the body, but that these losses may be prevented and large increases in body and visceral weight may be induced in such hypophysectomized birds by appropriate anterior pituitary hormone treatment during this same short period. It was further indicated that in pigeons prolactin is the pituitary

hormone which has special power to sustain and increase the size of body, intestine, liver, and pancreas. Schooley and Riddle have now tested the ability of two "growth" hormone preparations (supplied by others) to replace prolactin in these respects. Both of these "growth" hormone preparations were otherwise studied and found to contain marked quantities of prolactin (namely, 0.7 and 1.3 units per milligram) in addition to pituitary hormone other than "growth" hormone. Though these preparations produced favorable effects on size of body and viscera, under the conditions of our tests, these effects do not seem separable from their prolactin content.

A considerable effort was made to measure the extent to which the hormones produced by such organs as the thyroid, adrenals, and ovary can sustain weight of viscera and body in the pigeon hypophysectomized at 44 days, and likewise the replacement value of various vitamins in animals thus deprived of their pituitary glands. This study is unfinished, but in general it may be said that till now we have failed to obtain such a combination of these factors as will substitute for the special effect which the pituitary exercises on growth.

When the pituitary is removed from squabs 12 days old the exceedingly rapid growth which normally occurs during the next 3 weeks is much reduced, and it could not be maintained at or near the normal level through administration of any pituitary hormones or extracts utilized by us. In such injected birds neither bone development nor body weight keeps the pace observed in the unoperated animals. These failures, however, appear to be associated with inadequate or inappropriate food supply and perhaps with digestive disturbance. At this stage in the birds' life, when most extraordinary quantities of food are required, it seems probable that their digestive capacities become diminished after their crop-sacs

thicken and begin producing crop-milk under the action of prolactin.

In Brown Leghorn chicks whose pituitaries were removed at the age of 37 days, the rate of bodily growth decreased at once, and this rate remained subnormal until the birds were sacrificed for measurement of their visceral organs at 100 days. The general effects of hypophysectomy as observed in pigeon and fowl indicate that these effects are quite similar and comparable in birds and mammals.

SUPRARENAL AND PITUITARY RELATIONSHIPS

Last year a report was made upon the cytological criteria which indicate secretory activity in cells of the suprarenal cortex. It is known that both growth and secretion in these cells is sustained, directly or indirectly, by some product or products of the anterior pituitary gland. The available methods for assay of this product of the pituitary, called adrenotropin, are either insufficiently tested or relatively difficult to use. During the present year Miller and Riddle have utilized two types of information obtained from the suprarenals of pigeons as a method of assay and have compared these with an earlier known method of assay of adrenotropin.

It was found that increase of weight in the adrenals of normal immature (40 to 55 days) pigeons and degree of maintenance of adrenal weight in these pigeons during 10 days following hypophysectomy, and also cytological evidence of stimulation in the cortical cells of these two types of birds, agree satisfactorily with Moon's method of assay of adrenotropin in 21-day rats. Moreover, as tested by these three methods the ability of pituitary extracts to stimulate cortical tissue is found to be independent of their prolactin, gonadotropin, and thyrotropin potencies. These facts and

agreements provide support for the view that the pituitary produces a distinct adrenotropic hormone.

Similar studies were made to determine the action of several extra-pituitary hormones on the cortical cells of pigeons. Gamone (from post-menopausal urine of women) markedly stimulates both cortical and medullary tissue in both normal and hypophysectomized pigeons. Estrone stimulates cortical tissue in normal birds. Thyroxine, plus vitamin supplements, gave evidence of ability to stimulate cortical tissue in normal and hypophysectomized pigeons.

HORMONAL BASIS OF MATERNAL BEHAVIOR

A study of the hormonal basis of maternal behavior in virgin and adolescent male rats has been extended by Riddle and Lahr through a fourth year of investigation. Nearly 500 tests have been added to the 1780 reported last year. Though some hormones of interest to this study have recently become available in crystalline or synthetic form, it is expected that this research will be concluded at an early date and a final report upon it be made next year.

GENETIC HERMAPHRODITISM IN PIGEONS

Three years ago, we reported the occurrence of a family of hermaphrodites in our colony of pigeons. Six hermaphrodite offspring of a true hermaphrodite parent were then noted and briefly described. Further breeding and study of this group by Riddle and Schooley has now disclosed 21 hermaphrodites distributed over five generations. It is now clear, therefore, that we here have a strain or race of hermaphrodites, and such an instance seems to be unique among records for both birds and mammals. In each generation some normal males and normal females are found in addition to the true hermaphrodites. Thus far it has been possible to use the

hermaphrodites as male parents only, although these birds possess fairly large amounts of ovarian tissue which often produces estrogenic hormone in amounts sufficient to maintain their (left) oviducts in functional state. Within this strain the percentage of infertile eggs is high, but it seems capable of survival and of supplying data sufficient for a full study of the several interesting questions involved.

BASAL METABOLISM IN FUNCTIONAL REGULATION

Though heat production is being measured for several purposes, we here note that the information provided by these measurements has become nearly or quite indispensable to investigations on the action of hormones. Even such a by-product of these measurements as the "respiratory quotient" becomes of special value wherever effects of a hormone on carbohydrate or fat metabolism are under study. During the present year Riddle and Smith have made special effort to obtain what may be called baseline information on the heat production of young pigeons of the precise type and age used in our numerous assays of endocrine products. In this work it is found necessary to make the measurements at a variety of temperatures—15°, 20°, 25°, 30° C—and to make measurements at all these temperatures on birds non-fasted, others fasted for 24 hours, and still others fasted for longer periods. This latter need arises from the circumstance that pigeons refused to take food while being injected with certain hormones (intermedin, gamone, etc.), though injections must continue during several days in order that full effects of the hormone may have time to develop.

Last year we tentatively reported the unexpected result that at 5, 7, and 10 days after the removal of their pituitaries young pigeons, subjected to com-

plete fasting following this operation, lose a smaller percentage of their normal heat production than do their normal unoperated mates. Further study has confirmed that result.

RELATION OF PITUITARY TO CARBOHYDRATE AND FAT METABOLISM

It was earlier reported by Riddle and Dotti that prolactin is capable of increasing the blood sugar of normal and pituitaryless pigeons and also of New Zealand rabbits, but not of rats. Studies being conducted in other laboratories lead some or many to the view that the known influence of the pituitary on carbohydrate and fat metabolism is exercised by special hormones, sometimes called "diabetogenic" and fat metabolism hormones. If such hormones exist, this in itself is a matter of great consequence to laboratories like our own, in which much effort is directed to the purification of one or another pituitary hormone and to exhaustive assays of the preparations obtained in these procedures. It is essential that we learn whether the unquestionable effects of the pituitary on the utilization of sugar and fat are mediated by hormones already well identified or by other distinct substances which must be taken into account in attempts to purify any pituitary hormone whatsoever. Moreover, the safe or extensive use of any pituitary hormone or extract in medicine presumes at least some information concerning its influence upon the metabolism of sugar and fat. Some aspects of this problem have been under study by Riddle and Senum during a part of the present year.

Measurements were made of effects of various pituitary hormones and extracts, and also of thyroxine and estrone, on the sugar, fat, and acetone bodies of the blood (pigeons, rats, rabbits); on the sugar and acetone bodies of the urine

(rabbits); on liver and muscle glycogen and on liver fat (pigeon, rat). Though this unfinished study permits only few and tentative conclusions, we are impressed with the ability of practically all these preparations to evoke change or defective regulation of phases of carbohydrate or of fat metabolism (or of both) in one or more of the species studied. There is perhaps equal reason to be impressed with the rôle of species and of individual differences in some of these changes. Unfractionated pituitary extracts, the "glycotropic" preparations of Young (which contain non-negligible amounts of prolactin), and prolactin all appreciably increased the blood sugar in pigeons and in some rabbits but not in rats. The ketogenic preparations of Shipley and Long induced very marked acetonemia in hypophysectomized and normal rats, gave less marked results in pigeons, and had little or no effect in rabbits. On the other hand, prolactin produced acetonemia in pigeons but not in rats.

Of special interest are results obtained on the factor regulating increases of blood fat. Though some aspects of the subject are still obscure it was found that the injection of certain extracts of the anterior pituitary may increase the amount of blood fat by 20- to 50-fold within less than a week (B, C, fig. 1) in pigeons and rabbits. Later, in pigeons it was shown (E, fig. 1) that estrone, a product of the ovary, would more quickly do the same thing. It therefore seemed well to investigate in pigeons the extent of the changes in concentration of blood fat which accompany their own increased production of estrone just preceding ovulation. The amazingly large increases of blood fat which were thus found to occur in the normal life of female doves and pigeons, and in females only, are shown by smoothed curves (A and D) in the figure.

THE CHANGING ORGANISM

During the year Riddle made and published a survey or estimate of the features of constancy and of change as these have presented themselves in studies made on the pigeon. It was concluded that outward form and features of a higher organism give impressions of constancy which are proved illusory by measurement of varied, profound, regular and irregular internal change. Much of the constancy of an organism is a constancy of change. Our measurements are made not merely upon an organism

but upon a changing organism. The basic source of these many slow or swirling tides of change doubtless dips into the complexity that attends all life processes, but it is also evident that the several categories of change which have proved so marked and measurable in the pigeon rest largely upon mediations of the anterior pituitary gland. The nervous system and brain seem less involved. Anterior pituitary and brain together direct these numerous flowing adjustments which characterize and propagate the organism.

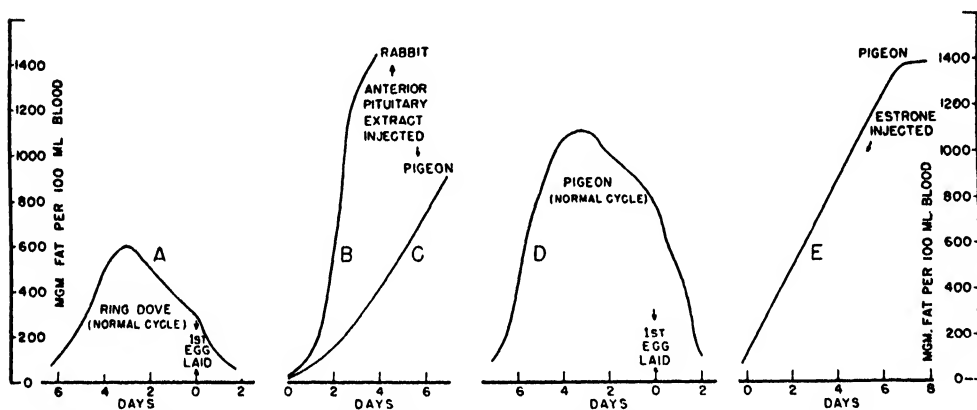


FIG. 1. Showing the very large natural increase of fat in the blood of female ring doves (A) and pigeons (D) during the days when their eggs (yolks) are forming. Also the increase of blood fat under the influence of anterior pituitary hormone in rabbits (B) and pigeons (C), and under estrone injections (E) in young pigeons of both sexes.

ANTHROPOLOGY AND HUMAN GENETICS

MORRIS STEGGERDA AND RUTH C. BATE

ANTHROPOMETRY

Negro women. About 60 measurements were made on 100 Negro girls from Tuskegee Institute. These were compared with a similar set of observations on Smith College students.¹ The mean age for the Tuskegee group is $20.05 \pm$

0.13 years and that of the Smith College group is 20.15 ± 0.07 , making them comparable in this respect. A uniformity may likewise be observed in weight and stature, making the study of body proportions one of considerable interest. The average weight for Tuskegee girls is 56.26 ± 0.53 kg. and their height is 1633.10 ± 4.55 mm. For Smith College girls these figures are 55.59 ± 0.82 kg. and 1628.05 ± 3.75 mm. respectively.

It was found that the Negro girls have,

¹Morris Steggerda, Jocelyn Crane, and Mary D. Steele, One hundred measurements and observations on one hundred Smith College students, *Amer. Jour. Phys. Anthropol.*, vol. 13, no. 2 (July-Sept., 1929).

on the average, a chest girth of 806.60 ± 3.37 mm., a shoulder breadth of 370.10 ± 1.05 mm., and a pelvic breadth of 276.20 ± 1.16 mm., showing them to be larger than the white girls, who average 793.90 ± 2.47 mm., 356.05 ± 1.02 mm., and 248.95 ± 1.06 mm. respectively for these measurements. On the other hand, the white girls, with an average sitting height of 868.40 ± 2.00 mm., surpass the Negro girls, whose sitting height is 837.40 ± 2.11 mm., indicating the long trunk of the whites or conversely the long legs of the Negroes. In fact, the Tuskegee students are longer than Smith girls in all linear measurements of the appendages. The span of the Negroes is 1709.10 ± 5.78 mm., and of the whites, 1640.25 ± 4.52 mm., implying a difference which shows even more clearly in the index designated relative span or span divided by stature. For Tuskegee girls this index is 104.58 ± 0.19 per cent and for Smith girls 99.41 ± 0.10 per cent, representing a difference which is highly significant statistically.

This investigation, like other anthropometric studies of the Negro race, shows Negro girls to be more dolichocephalic than white girls, their heads being 189.28 ± 0.46 mm. long and 144.50 ± 0.30 mm. wide, as compared with 186.43 ± 0.38 mm. and 145.98 ± 0.29 mm. for whites. The Negroes have broader noses than the whites, as is clearly shown in their nasal index (nasal breadth over nasal length) of 69.54 ± 0.37 per cent. This is considerably higher than the index of 63.71 ± 0.39 per cent for the Smith College students. Likewise, the aural index of 61.64 ± 0.28 per cent for the Tuskegee girls indicates that they have more circular ears than the Smith girls, whose index for this measurement is 56.31 ± 0.29 per cent.

Cephalic index of Navajos. It is commonly believed that Navajo Indians are brachycephalic because, as infants, they are put on a cradleboard. To test this

hypothesis a study was made in which two groups of children were compared, one in which a cradleboard had been used during infancy and another in which no cradleboard had been used. Owing to the low percentage (estimated to be less than 10 per cent) of all Navajo children who are never placed on the board, it was difficult to obtain a large number of individuals in this group.

The mean cephalic index of 72 male children who have spent some time on the cradleboard is 87.61 ± 0.32 per cent, which is significantly higher than that of 85.13 ± 0.58 per cent for 30 male children in the other category. Similarly, the mean index of 86.88 ± 0.41 per cent for 51 females who had been on the board is significantly different from that of 83.93 ± 0.57 per cent for the 41 cases where the board had not been used.

It was suggested that the differences observed might be due to differences in the age composition of the groups. Correlations were made between the cephalic index and age of the individual at the time of measurement and all were negative and of a relatively low order, for example, -0.32 ± 0.07 and -0.07 ± 0.09 for male and female children where the cradleboard was used and -0.11 ± 0.12 and -0.45 ± 0.08 for the male and female children where the cradleboard was not used. Thus age was not responsible for the differences in cephalic index in the two groups, and it may be concluded that the use of the cradleboard does increase the cephalic index. The fact that Navajo children who have never been on the cradleboard are still brachycephalic indicates that it is probably a racial characteristic.

Dynamometer readings on children. A comparative study was made on the mean hand grip for the left and right hands of male and female children of four different races using the Kry Sheerer dynamometer. The results

showed that Maya and Navajo Indian children have a lower hand grip than whites and Negroes of corresponding ages. For instance, Maya male children in the 10 to 14 years age group have a right-hand grip of 11.61 ± 0.19 ; Navajos, 16.33 ± 0.18 ; Dutch whites, 19.05 ± 0.24 ; and Negroes, 20.06 ± 0.37 . This sequence of increasing strength of grip holds true for both males and females in all age groups considered (6 to 9, 10 to 14, 15 to 18 years), the Maya having consistently the weakest hand grip and the Negroes the strongest. A marked sex difference in strength of hand grip is shown, the males of all four races in each age group being stronger than the females. In the 15 to 18 years age group, the strength of right-hand grip for males is: Maya, 21.36 ± 0.53 ; Navajo, 31.98 ± 0.33 ; Dutch white, 35.50 ± 0.34 ; Negro, 33.31 ± 1.26 . For females of the same groups, the average right-hand grips are 17.25 ± 0.35 , 22.22 ± 0.18 , 22.50 ± 0.22 , and 26.82 ± 0.42 respectively. It was also found that the right hand is generally slightly stronger than the left in each age group of each race.

A study was also made of the correlation between hand length and strength of grip. It was found that there exists a positive correlation between these factors. The correlation coefficients for the male children of 12 years of age for Maya, Navajo, Dutch white, and Negro are, respectively, -0.50 , -0.42 , -0.34 , and -0.56 . No correlation exists between the hand grip and the hand index. The authors are aware of the psychological factor involved in determining hand grip. For example, among whites and Negroes the spirit of competition appears to be greater than among the Indians.

Weights of newborn Navajo babies. Weights of 102 Navajo male babies and 106 Navajo female babies were found to be 3266 ± 32.8 and 3028 ± 30.1 grams respectively. These figures are statistically

smaller than those reported by Kugler² for white babies from Zürich and also by Freeman and Platt for white babies of New York City.³ Navajo babies, on the other hand, are larger than Negro babies from Jamaica, B. W. I., as reported by Davenport and Steggerda.⁴ The differences between the last two named races are not as pronounced, however, as between Navajos and whites. There exists in the literature much information on birth weights of children, but only a few studies report their averages with probable errors.

Twins. Among the 400 children measured annually who constitute the author's growing series, there have been 26 pairs of so-called identical twins. This year a study of the likenesses of these twins and their dissimilarities has been begun. The figures for these twins have the significance of having been obtained over a period of years, that is, some of these sets of twins have been measured for nine consecutive years. Thus, the comparative growth of identical twins will form the basis of this study.

ETHNOLOGY

The food of the Navajos. A study made by Benedict and Steggerda in 1936⁵ on the food habits of the Maya showed that their diet consisted chiefly of maize. For comparative purposes, a similar study was made on the Navajos in southern New Mexico and Arizona from 1934 to 1936.

² Erica Kugler, *Körperproportionen und Kopfform bei Neugeborenen* (Zürich, 1932).

³ Rowland G. Freeman, Jr., and Virginia Platt, *Skeletentwicklung und Wachstum der Säuglinge von der Geburt bis zu einem Monat*, *Anthropol. Anz.*, vol. 9, no. 1, pp. 68-78 (1932).

⁴ Charles B. Davenport and Morris Steggerda, *Race crossing in Jamaica*, *Carnegie Inst. Wash. Pub. No. 395* (1929).

⁵ Francis G. Benedict and Morris Steggerda, *The food of the present-day Maya Indians of Yucatan*, *Contributions to American Archaeology*, vol. 3, *Carnegie Inst. Wash. Pub. No. 456*, pp. 155-188 (1936).

One portion of the study was completed this year in collaboration with Dr. Thorne M. Carpenter of the Nutrition Laboratory. Sixty-six samples of foods in the Navajo's daily diet, both cooked and uncooked, were analyzed for fat, nitrogen, and water content and energy value. It was shown that in spite of the variability in fat and nitrogen content of the different foods, the energy content was relatively constant in most instances (between 3.5 and 4.5 calories per gram of air-dry matter). Higher energy values were found for the meats and some of the berries and seeds, which had higher percentages of fat.

Mutton is the chief food of the Navajos, and practically all parts of the animals (sheep or goats) are eaten. The average family of 6 or 7 persons eats 1 goat each week, 10 kg. of flour, 2.5 kg. of white sugar, 1 kg. of coffee, and such vegetables as may be available.

Corn is used to a less extent by the Navajos than by the Maya. It is prepared by both of these peoples in a great

variety of ways. The authors are preparing a paper at present on the Navajo methods of preparing corn flour, bread, dumplings, and mush in addition to the manner of cooking and preserving various fruits, vegetables, nuts, and berries.

Plants used by the Maya. In the annual report of 1938 a discussion was given of the ethnobotany of the Maya Indians, considering chiefly the plants used for medicinal purposes. This year two samples were gathered from a plant called *tuk* in Maya, *Acromia mexicana*, one from the roots and the other from the central stem. These and the roots of *x-kan-lol*, *Tacoma stans* L., are said by the Maya to be beneficial in the treatment of diabetes. The three samples are being clinically assayed at present to determine their true medicinal properties. Likewise, the seeds of the *ramon* tree, *Brosimum Alicastrum* Sw., are being assayed. They are said by the Maya to contain a milk-producing agent for nonlactating mothers.

RESEARCHES IN EUGENICS AND HEREDITY

HARRY H. LAUGHLIN

THE HUMAN RESOURCES OF CONNECTICUT

Purpose. For two years, beginning October 1, 1936, this experimental state survey of human resources was a joint research of the State of Connecticut and the Carnegie Institution of Washington, represented by the Eugenics Record Office.

Report Number One, dated October 1, 1938, treats mainly that field of study which the authorizing Connecticut statute emphasized, namely, a consideration of "the prevention, treatment and care of mental diseases and defects." And, following the statute's secondary authorization, "to consider allied problems," this report indicates also a number of definite subjects for research, and

the type of firsthand field data and analyses necessary for future consideration if the state not only proposes to have in hand adequate data better to attack the care and training of its inadequate and handicapped classes, but also intends a still more earnest attempt to prevent the relative increase of human defectives within its future population.

This Survey of the Human Resources of the State of Connecticut is the pioneer effort in this particular field. In purpose and form it is comparable with surveys of natural resources which many states have undertaken in other specific fields, such as agriculture, forests, wild life, minerals, water, and the like—fields other than the natural quality of the

state's own human stock. The present experiment is meant to pave the way for a new type of state survey which individual states can follow and perfect.

The firsthand field studies continued from the Hartford center until the end of December 1937, when the headquarters were transferred to the Eugenics Record Office at Cold Spring Harbor, and the investigations began the second stage of their development, namely, bringing the field work to a definite head and concentrating efforts on the analysis of its findings with a view to preparing Report Number One, which would examine into the factors of heredity and environment as causes of individual handicap and social inadequacy among citizens of the state.

The report of the Survey. Report Number One (in five parts) covers researches from the beginning of the Survey, October 1, 1936, to October 1, 1938. It is:

"An inquiry into the basic problems which concern family-stock betterment in Connecticut; a statement of the problems involved and the technique of their analysis; with special reference to reduction in the number of individually defective and handicapped persons produced by or resident within the State; and a consideration of the possibility of effective State guidance, in the turnover of population from generation to generation, toward the State's established population-pattern in number, race and inherent qualities of body, mind and spirit."

Part I. Family-stock betterment in Connecticut (69 pages).

Part II. Eight handicapped families of Connecticut in each of which feeble-mindedness is common (85 pages, 8 folded pedigree charts).

Part III. The laws of Connecticut which bear upon the conservation of the population of the Commonwealth in numbers, race and inborn quality (128 pages).

Part IV. Portfolio of fifteen charts. Lot *a*, nine charts on special race betterment problems in Connecticut (charts 1 to 9); lot *b*,

six charts on the problem of feeble-mindedness in Connecticut (charts 10 to 15).

Part V (unpublished). Three hundred forty-six tables of cross-classifications of qualities and conditions of selected natural groups among the subjects of the present survey, which tables supply data and analyses for the text of the report as written. (For the purpose of publication, part V is omitted on account of its bulk, and a short abstract—showing its nature and use, and giving a few sample tables—is included under the same cover with part IV.)

Up to date—June 30, 1939—a mimeographed edition of 25 sets of the first four parts of the report has been made and distributed.

RESEARCHES ON THE BIOLOGICAL ASPECTS OF IMMIGRATION

By personal collaboration with the Committee on Immigration and Naturalization of the Chamber of Commerce of the State of New York, headed by Captain John B. Trevor, and with the subcommittee of the U. S. Senate on certain immigration bills, under the chairmanship of Senator Robert R. Reynolds of North Carolina, Dr. Laughlin has continued his studies on the biological aspects of human migration. Firsthand facts pertinent to current problems were collected, systematized, and analyzed and the findings published in a report of researches entitled *Conquest by immigration*, by Harry H. Laughlin, which was issued on May 15, 1939, by the Chamber of Commerce of the State of New York.

RESEARCHES ON THE INHERITANCE OF RACING CAPACITY IN THE THOROUGHBRED HORSE

Two tools—the *yardstick* for the measurement of racing capacity in the individual Thoroughbred and the *probability-resultant* for computing near-kin resemblances—having been perfected for use, the main studies of the year on the

Thoroughbred horse concern the use of these new tools in 100 test cases, each of which sought to predict the racing capacity which each foal would inherit, and to compare such prediction with the subsequent racing capacity which the particular subject actually developed. In each of these 100 cases every race which each selected near-blood kin and the subject itself ran, and which was truly run and well ridden on a good or fast American earth track, was duly judged in quality of performance on the basis of sex, age, weight-carried, distance-run, and speed—all such factors duly intercompensated. In each foal-prediction case only those race-performance records which existed among near-blood kin just prior to the time of mating of the sire and dam of the particular subject-foal were used as prediction-evidence.

The Mendelian tryout. All agree that racing capacity is highly hereditary in the Thoroughbred horse. During the early stages of the present researches on the genetics of the Thoroughbred horse, efforts were made to analyze the inheritance of racing capacity on the Mendelian basis, that is, to postulate high racing capacity, or racing capacity of a given degree of excellence, as contrasted with "no racing capacity," as based upon 1, 2, 3, or, at most, only a few Mendelian units. Such attempts failed to find a solution, possibly because that quality which is called "racing capacity" is an exceedingly complex thing; it may be the physiological resultant of the interaction of a great number of genes, in the course of individual development. Each such gene may be a Mendelian or genic unit with its own anatomical, chemical, physiological, or temperamental influence, which enters as a developmental factor into racing capacity, which is a somatic end-product, either as a segregable and complete end-unit or factor, or as an

active, dependent, developmental, or enzyme-like influence on other factors.

Manerkonic analysis. $K=f(M,R)$. The main finding of the attempt in Mendelian analysis was that, if advance in the genetics of the Thoroughbred horse was to permit any sort of success in the prediction of hereditary racing capacity in the prospective foal, a new method of attack would be necessary. This new technique called first for defining the quality called "racing capacity," for working out its diagnostic elements and standards, and for measuring it exactly. Then the racing records of the individual Thoroughbreds—members of the particular near-kin group used as a prediction-basis—would have to be analyzed, their training studied, and, so far as possible, the hereditary and environmental factors of their specific abilities determined.

In 1000 cases of measured racing capacity (RC) for each pair of blood-kinships—such as dam-foal, brother-sister, or sire's sire-foal, and so on through a score of nearest blood-kinships—the mathematical relationship of measured racing capacity for each kinship-pair was worked out. In each such work-out $K=f(M,R)$, the prediction-bases or M (standing for *manton*, or "prophet") are the measured racing capacity of the particular kin upon which the particular prediction is based; R or quality predicted (standing for *ergon*, or "the real thing") is the measured racing capacity in the individual or subject-foal about which the prediction is made; and K (standing for *eikon*, or "likelihood"), or probability, ties up the two relationships M and R . Thus by distributing the measures of M along the y -coordinate, the values of R along the x -coordinate, and the values of K along the third-dimensional or z -coordinate, each measured prediction-system becomes a saddle-like structure called the "manerkon." This was completed, for each of the

nearest blood-kinships involved as factors, according to the newly worked out principles and techniques for the genetic analysis of racing capacity. (See Year Book No. 35 [1935-1936], p. 65, and Year Book No. 36 [1936-1937], p. 68.) Thus each manerkon, based upon 1000 kinship-pairs of American Thoroughbred racing stock, shows how, in racing capacity, the particular near-blood kin resembles the propositus or foal about which the prediction is made, when all other factors are randomly represented.

Thus in its structure each manerkon possesses that particular piece of prediction-evidence, in the form of a probability-distribution, supplied by the particular kinship, of that racing capacity to be developed in the future foal. Of course, any foal *might* develop any quality of racing capacity within the whole

range, but the *probability* of the development of each measured racing capacity from the highest to the lowest is duly computed as a prediction, a probability, or an expectation. If subsequently the foal actually comes into existence and develops a measured racing capacity, this capacity is indicated in relation to the particular probability-distribution prediction-area, to its position in relation to racing-capacity value at the fluctuation-center (*fc*) or the highest probability-prediction, and to other features of the probability-prediction area. When enough foals to represent a fair sample of the particular population have been made subject to such prediction, the "goodness of prediction" in the particular kinship is then computed; and useful criticism of the basic principles and techniques used is made possible.

NUTRITION LABORATORY¹

THORNE M. CARPENTER, ACTING DIRECTOR

In the research program of the Nutrition Laboratory are included studies of the factors governing heat regulation and heat production in animals and humans. Among the objectives of such studies are the development of methods of measuring body temperature and the determination of the limits of normal body temperature. Another objective is the establishment of standard values of heat production for different animal species, including humans. These standard values are useful for comparative purposes, because they are based on measurements of the heat production made under well-defined and reproducible conditions when the heat production is at the minimum level compatible with life, unaffected by such factors as activity and digestion of food. Measurements of the minimum heat production of animals in any one species, obtained under similar conditions, may be compared with the standard values for that particular species, to determine whether the experimental animals under study are in a normal or pathological state, and the standard values for different animal species may be compared among themselves to note the differences in the heat production of the different species. In these studies there is the problem of whether the heat production must be determined directly by means of an apparatus for measuring quantities of heat (a calorimeter) or whether it can be determined indirectly by measuring the oxidation processes taking place in the body and calculating the heat production from the heat equivalent of a definite amount of oxygen consumed or carbon dioxide eliminated dur-

ing the oxidation processes. The total heat production is the sum of the amounts of heat developed by the intermediary processes going on within the body, whereby food (protein, fat, and carbohydrate) or body substance either is completely burned or is changed into another substance. To understand these intermediary processes, one must know how foods or body substance are used in the body, in other words, the rate of burning of these materials in the body and the rate of change from one substance to another.

During the past year a certain number of studies contributing to this program either have been completed or have progressed to such an extent that they provide information toward a solution of some of these problems. An apparatus has been described for measurement of the maximum temperature of the air exhaled from the human lungs. From this measurement the true temperature of the body itself can be estimated, and with the apparatus determinations of the body temperatures of large groups of humans can be made rapidly. This should prove to be an especially advantageous feature in routine physical examinations of school children and in general physical examinations at times of epidemics. The conditions under which the normal body temperature of the adult rabbit can be measured and the limits of its normal temperature have been established, so that other research workers now have a means of knowing whether or not their rabbits have abnormal temperatures in comparison with the normal standards.

The rabbit is used extensively in experimental investigations. The condi-

¹ Situated in Boston, Massachusetts.

tions necessary for the measurement of the minimum heat production of this species have been studied, and the basal metabolism, that is, the minimum heat production, of the rabbit has been established. As this animal species has a wide range in adult weight or size, formulas with respect to size have been derived from these measurements, whereby, if the body weight is known, it is possible to predict closely the probable minimum heat production of an adult rabbit. Therefore, measurements of the basal metabolism of rabbits in pathological conditions can now be compared with the standard metabolism of normal rabbits of the same size. The study is also a contribution to the larger investigation of the range in basal metabolism of animal species in general.

A research was undertaken in 1935 and 1936 on the effect of consumption of simple sugars such as grape sugar and fruit sugar on the heat production of a human subject, as measured directly by the calorimeter and indirectly by calculation from the simultaneously measured respiratory exchange (oxygen consumption and carbon dioxide elimination). The analysis of the results of this research has progressed far enough so that we now know that there is a difference, under some conditions, between the heat production as calculated from the respiratory exchange and the heat production as directly determined. This finding reopens the comparison of direct and indirect heat measurements and suggests that under some conditions the combustion of the body material is not completed at the time of the measurements, so that the actual heat production as measured by the calorimeter is not equivalent to the expected heat production calculated from the absorption of oxygen.

In an investigation on the utilization of the carbohydrates (sugars and starch) in foods commonly eaten by humans, such as boiled and raw vegetables, nuts, and fruits, the analyses of the foods have been completed. From measurements of the respiratory exchange of a subject who consumed individual portions of these foods containing equal amounts of carbohydrates, calculations have been made of the actual amounts of carbohydrates burned in the body following the consumption of the various foods. This study shows the differences in the availability (digestion and absorption) to the body of carbohydrates in common foods and the rates at which carbohydrates are burned in the body after certain foods are eaten.

Nutrition studies may include not only laboratory measurements of heat production and respiratory exchange after food ingestion, but also field investigations regarding the food habits of groups of people. An example of this latter type of study has been the collection of a large number of the foods commonly eaten by the Navajo Indians, either in the past or at the present time, especially wild plants and seeds that are not found in the white man's diet. Analyses of these foods have established their nutritive values (fat and protein content), their moisture content, and their heats of combustion or energy content. We now have knowledge of the kinds and the amounts of food consumed weekly by the average Navajo family and the chief sources of their foods. Historical and statistical nutrition studies are of value, as they may help to explain why races have survived either because of or in spite of their diets. This study of the foods of the Navajo Indians is what would be popularly considered a nutrition study.

STAFF NOTES

Mr. W. H. Leslie, who has been a member of the staff since the Laboratory was organized, was retired on November 1, 1938. Mrs. H. B. Lee resigned on February 1, 1939.

Dr. T. M. Carpenter attended the Sixteenth International Physiological Congress, held in Zürich, Switzerland, August 14 to 19, 1938. On the return trip from the Congress he visited the Office of Nutrition of the Ministry of Health in London, England.

On November 17, 1938, Dr. Carpenter spoke on "Alcohol" before the Alpha Chi Sigma Fraternity of the Massachusetts Institute of Technology in Cambridge. On March 12, 1939, he addressed the Emmanuel Club of Boston on "Calories." On March 17, 1939, he gave a lecture on basal metabolism to the first-year class at the Harvard Medical School, and on April 29, at the Fifty-first Annual Meeting of the American Physiological Society, at Toronto, he gave a paper (with Dr. Edward H. Bensley) on "Human direct and indirect calorimetry with sugars."

Dr. Carpenter was elected Chairman of the Northeastern Section of the American Chemical Society for 1939-1940, and a member of the Executive Committee of the Division of Biological Chemistry of the American Chemical Society for the year 1939. At its Sixth Annual Meeting, in Toronto, on April 26, 1939, he was re-elected Vice-president of the American Institute of Nutrition for 1939-1940. At this same meeting R. C. Lee presented a paper (by title) on "The basal metabolism of the rabbit."

A demonstration of the apparatus for determining the maximum temperature of expired air and a lecture on the same were given by R. C. Lee on May 1, 1939, at a men's gathering on the "Scientific Night" of the Pilgrim Fraternal Association of Boston.

Members of the Institution's Division of Animal Biology met at the Nutrition Laboratory on January 27 and 28, 1939. Demonstrations of apparatus and experimental procedures were given on the afternoon of January 27 and reports of investigations in progress on the morning of January 28. Those present were A. F. Blakeslee, M. Demerec, T. M. Carpenter, C. G. Hartman, R. C. Lee, E. C. MacDowell, O. Riddle, and G. L. Streeter. Guests present at either the demonstrations or the conference, or both, were two of the Institution's trustees, Dr. Thomas Barbour of Harvard University and Dr. L. H. Weed of Johns Hopkins University; Dean C. S. Burwell, M. O. Lee, H. C. Trimble, and G. B. Wislocki of the Harvard Medical School; F. L. Hisaw of Harvard University; A. T. Hertig and F. C. Irving of the Boston Lying-in Hospital; J. Rock of the Free Hospital for Women, Brookline; E. G. Ritzman of the Laboratory for Animal Nutrition, Durham, New Hampshire; Z. Y. Kuo of Hangchow, China; and L. G. Wesson of Boston.

Dr. Zing Yang Kuo, of Hangchow, China, has been a guest investigator at the Nutrition Laboratory, studying the physiology of the nervous system of the chick embryo. For this work a stipend was granted to him by the Rockefeller Foundation and space and facilities were provided by the Carnegie Institution of Washington.

Dr. Laurence G. Wesson, formerly pharmacologist at Veader Leonard Laboratory of Experimental Therapeutics in Baltimore, was a guest investigator at the Nutrition Laboratory in the fall and winter of 1938-1939, studying the Laboratory's technique for measurement of the respiratory exchange of small animals and the use of the Carpenter gas-analysis apparatus. Dr. Wesson continued his earlier researches on a specific factor for carbohydrate metabolism in rats.

The respiration apparatus installed by the Nutrition Laboratory in the Department of Embryology at Baltimore for study of the basal metabolism of monkeys has been temporarily placed at the disposal of Dr. Edward M. Bridge, of the Department of Pediatrics of the Johns Hopkins Hospital, for use in studying the metabolism of infants and children. Miss Eleanor A. Winter, his assistant, spent several weeks at the Nutrition Laboratory and received training in the technique of the Carpenter gas-analysis apparatus, with special reference to the study of respiratory quotients.

Mr. Edmund H. McNally, Assistant Biologist at the Bureau of Animal Industry of the U. S. Department of Agriculture, Washington, D. C., spent a week at the Nutrition Laboratory, studying the application of the Carpenter gas-analysis and the open-circuit respiration apparatus to the determination of the respiratory exchange of domestic fowl.

From time to time groups of students have visited the Laboratory and been conducted around the building. These have included students from the Harvard Medical and Dental Schools and the New York State College of Home Economics.

INVESTIGATIONS IN PROGRESS

Rectal temperature of the normal adult rabbit. A detailed study of the rectal temperature of the normal adult rabbit and the influence of various factors, such as depth of insertion of thermometer, external temperature, length of fasting, and time of day, has been carried to completion and the results have been published. (See page 215.)

Basal metabolism of the normal adult rabbit. The effects of various factors on the heat production of the normal adult rabbit have been studied, to formulate an explicit statement of the conditions prerequisite for the determination of the basal metabolism of this animal. Measurements of nearly one hundred rabbits have been made, to establish the level of the heat production of this animal. This problem, which has extended over several years, has been brought to completion by R. C. Lee, who was assisted in this study, as well as in the other studies on rabbits mentioned in this report, by G. Lee and H. B. Lee.

Relation between size and basal metabolism of the rabbit. A detailed analysis of the basal metabolism measurements on normal adult rabbits with reference to their body weights has been made, to determine whether there is any correla-

tion between basal metabolism and size within one animal species. As the rabbits used had a sevenfold range in adult weights, this animal species was ideal for the study. R. C. Lee has been aided in this problem by E. A. Wilson and S. E. Pinkham.

Insensible perspiration, environmental temperature, and metabolism of the rabbit. The relation between insensible perspiration and metabolism, found in man and some animals, has been investigated with the rabbit, to determine if such a relation exists in this species. In addition, the reaction of the metabolism to environmental temperatures below thermic neutrality has been established with the same group of animals.

Habituation to environmental temperature and metabolism of the rabbit. The influence on the basal metabolism of habituation to various controlled environmental temperatures has been studied with rabbits, to establish the extent to which this factor may cause variations in basal metabolism.

Body composition and basal metabolism of the rabbit. The bodies of rabbits whose basal metabolism had been established have been analyzed with respect to the percentage content of ash, bone,

nitrogen, fat, and moisture, to determine whether there is any correlation between basal metabolism and body composition.

Physiology of the chick embryo. During his stay as guest investigator at the Laboratory Dr. Z. Y. Kuo has traced the beginning and the development of acetylcholine in the chick embryo up to the twelfth day of incubation. This study has been completed, and the results have been published. (See page 216.) Dr. Kuo has also made a study of the sensitivity of the chick embryo to electrical stimulation after injection of the proper dose of strychnine into the amnion sac. The development of walking in the chick was traced from the earliest beginning during incubation to hatching and during the first day after hatching. The major portion of the data on locomotion in the chick was gathered while Dr. Kuo was working in other laboratories, but the study was completed in the Nutrition Laboratory.

Basal metabolism of the rabbit in experimentally produced atherosclerosis. The study of experimentally produced atherosclerosis in adult rabbits by the feeding of cholesterol has been continued, in cooperation with Dr. Timothy Leary, Medical Examiner of Suffolk County, Massachusetts, but as yet the findings are inconclusive. Observations are now being made on young rabbits. The basal metabolism studies are being carried out by G. Lee, under the supervision of R. C. Lee.

Effect of ingestion of hexoses on the respiratory quotient of the goat. The observations on the effect of the ingestion of simple sugars on the respiratory quotient of the goat have been continued and completed. This was made possible through the cooperation of Professor E. G. Ritzman, of the Laboratory for Animal Nutrition of the University of New Hampshire, and the assistance of the college veterinarian, Dr. C. L. Mar-

tin. The respiratory exchange measurements were made by B. James.

Effect of ingestion of hexoses on the respiratory quotient of the cat. In continuation of the general program of study of the biological variations in the response of the respiratory quotient to the ingestion of simple sugars, observations have been made on four cats. These were fed glucose, fructose, and galactose, introduced by stomach tube, and the respiratory exchange of each was measured for several hours thereafter. The observations have been made by B. James with the assistance of M. Stankard.

Electrical method of gas analysis. The construction of an apparatus like that devised by Professor A. K. Noyons of the University of Utrecht, Holland, has been completed by V. Coropatchinsky. The apparatus is now being standardized by him for the determination of the carbon dioxide and the oxygen content of gaseous mixtures of composition similar to those that occur in open-circuit respiration apparatus when in use for study of the respiratory exchange.

Respiratory failure in newborn infants. To combat respiratory failure in newborn infants of diabetic mothers, Dr. Priscilla White of the New England Deaconess Hospital has, on several occasions, made further use of the Nutrition Laboratory incubator. Mr. R. C. Lee has rendered assistance in its use. The clinical experience with the incubator has been of such value that a description of the equipment and a statement of the experience with it has been prepared for publication.

Analysis of foods used by Navajo Indians. Between 1934 and 1936 Dr. Morris Steggerda of the Department of Genetics collected a large number of samples of plant and animal foods used at the present time by the Navajo Indians. These have been analyzed with respect to the conventional grouping of nutrients by

M. Stankard, and the heats of combustion have been determined by B. James. The results of the analyses have been calculated, and a publication presenting the results has been completed. (See page 217.)

Effect of ingestion of foods on the human respiratory quotient. The study begun last year on the effect on the respiratory quotient of giving to a human subject portions of common foods containing approximately 25 grams of carbohydrates has been continued. Samples of these foods have been analyzed not only with respect to the conventional grouping of nutrients but also with respect to the differentiation of the various forms of carbohydrates. The results are now being calculated for publication. The chemical analyses were made by M. Stankard and the determinations of the energy content by B. James.

Metabolism in diabetes mellitus. A

helmet open-circuit respiration apparatus for humans has been placed in the Baker Clinic of the New England Deaconess Hospital, and observations are being made frequently of the respiratory quotients of diabetic patients with reference to the use of insulin and the dietetic regimen. Particular attention has been paid to patients who have a high resistance to insulin and require large quantities for treatment. The respiratory exchange has also been studied of diabetics about to undergo surgical operations, as in these instances the possibility presented itself of comparing the glycogen content of the tissues with the respiratory quotient at the time of operation. This investigation is being carried on with the cooperation of Dr. H. F. Root and Dr. A. Marble of the New England Deaconess Hospital. The respiratory exchange measurements are being made by B. James.

LITERARY WORK

A manuscript by F. G. Benedict, Priscilla White, and R. C. Lee has been completed, describing the infant incubator and respiration chamber mentioned on page 213.

Two papers, one on "The basal metabolism of the adult rabbit and prerequisites for its measurement" and the other on "Size and the basal metabolism of the rabbit," have been completed by R. C. Lee and submitted for publication. A report on "The rectal temperature and the basal metabolism of the wild cottontail rabbit" is also in preparation by him.

To complete his studies at the Nutrition Laboratory, preparatory to return-

ing to China, Z. Y. Kuo is writing two reports entitled "Studies in the physiology of the embryonic nervous system. III: The origin and development of locomotion in the chick" and "V: The effect of strychninization on the reflex activities of the chick embryo."

Reports are in preparation by T. M. Carpenter on "The composition of some common foods with respect to the carbohydrate content" and on "The combustion of carbohydrates by humans after ingestion of common foods."

The preparation of the manuscripts and the editorial work has had the capable supervision of the editor, Elsie A. Wilson.

PUBLICATIONS

- (1) *The maximum temperature of expired air as a rapid measure of human body temperature.* Francis G. Benedict, Cornelia G. Benedict, Robert C. Lee, and Helen B. Lee. New England Jour. Med., vol. 219, pp. 509-515 (1938).

The maximum temperature of the air expelled from the lungs in a single expiration is measured by a thermoelectric method employing a galvanometer and two thermojunctions. The subject (at room tempera-

ture) refrains from talking and breathing through the mouth for 2 minutes, then draws a moderately deep breath, holds it for 5 seconds, and exhales into a mouthpiece housing the measuring junction. Exercise, breathing cold air, and drinking cold liquids should be avoided for 15 minutes before such measurements. The true rectal temperature of the normal and of the febrile individual can be approximated within $\pm 0.5^{\circ}$ F by adding 2.2° F to the maximum temperature of the expired air. These measurements can be made at the rate of four per minute. The method is particularly suited for rapid temperature measurements on large groups of individuals during epidemics of colds and influenza.

- (2) *The cooperative researches of the Nutrition Laboratory.* Francis G. Benedict. Cooperation in research, Carnegie Inst. Wash. Pub. No. 501, pp. 251-258 (1938).

An outline is given of the investigations undertaken by the Nutrition Laboratory in cooperation both with other departments of the Carnegie Institution of Washington and with outside institutions. The studies of racial metabolism are cited as a striking illustration of the effectiveness of cooperative investigation by research organizations.

- (3) *Biographical memoir of Henry Preniss Armaby, 1853-1921.* Francis G. Benedict. Nat. Acad. Sci. Biograph. Memoirs, vol. 19, 8th memoir, pp. 271-284 (1938).
- (4) *The electrocardiogram of the elephant.* Paul D. White, James L. Jenks, Jr., and Francis G. Benedict. Amer. Heart Jour., vol. 16, pp. 744-750 (1938).

Electrocardiograms were obtained from nine circus elephants, whose heart rates ranged from 24 to 53 per minute (average, 35 to 40). The points of particular interest in the analysis of these electrocardiograms are the relatively low amplitude of all the complexes (P, QRS, and T waves) in the three classical leads, with greatest excursion in lead I, and the unexpected length of the various time intervals (P-R interval, QRS wave, and duration of systole as measured from the onset of the QRS wave to the end of the T wave). The low amplitudes are not explained by artifact or disease but are evidently characteristic of elephants' electrocardiograms. The various time intervals noted are beyond the measurements to be

expected at slow heart rates in the case of mammals of average size, like man, and may be explained by the great size of the elephant's heart, its longer paths of impulse conduction, and its greater bulk of contracting muscle.

- (5) *Animal metabolism: from mouse to elephant.* Francis G. Benedict. Science in progress (Sigma Xi Lectures), pp. 255-291. New Haven, Yale Univ. Press (1939).

A survey is made of the energy metabolism of the many different animal species (warm- and cold-blooded) studied by the Nutrition Laboratory over a period of three decades. The details of this survey have been published in Carnegie Institution of Washington Publication No. 503 (1938). The marked differences found in the heat production of various animal species having the same weight and hence the same surface area (calculated from weight) make it evident that there are great differences in the heat-producing powers of these animals. The data offer a striking contradiction of the long-maintained belief that the basal heat production per unit of surface area is constant among all warm-blooded animals. Inquiry should now be directed toward discovering why metabolism varies so greatly in animals of the same weight and the same surface area. To what extent, if at all, these differences may be based upon purely physical loss of heat and to what extent they are based, as is probable, upon differences in chemical composition of the body and the blood, the oxygen-carrying power, the minute circulation, and especially the distribution of the blood, remains to be solved.

- (6) *The rectal temperature of the normal rabbit.* Robert C. Lee. Amer. Jour. Physiol., vol. 125, pp. 521-529 (1939).

The conditions for accurate rectal temperature measurements of the rabbit are specified. As there is a gradient in the temperature of the rectum, the thermometer should be inserted 75 mm. or more. Activity should be avoided for at least 30 to 60 minutes prior to measurement. Ingestion of food causes only a slight increase in body temperature. Between 10° and 28° C the environmental temperature does not affect the rectal temperature, provided the rabbit has been living at the same environmental

temperature for at least 24 hours. But if the external temperature rises to 32°, a temporary increase in body temperature occurs, which disappears after the rabbit has remained for 24 hours at 32°. Fasting for 24 hours at 10° to 28°, for 72 hours at 24° to 28°, and for 3 weeks at 27° to 30° does not affect the body temperature. There is no sex difference and no diurnal variation in rectal temperature, either with rabbits on food or fasting up to 60 hours. The range in normal body temperature is from 38.4° to 41.1° C, and the average is 39.6° C.

- (7) *The basal metabolism of the rabbit*. Robert C. Lee. Jour. Nutrition, vol. 17, supp., pp. 19-20 (1939).

Abstract. (See page 211.)

- (8) *Studies in the physiology of the embryonic nervous system. IV: Development of acetylcholine in the chick embryo*. Zing Yang Kuo. Jour. Neurophysiol., vol. 2, pp. 488-493 (1939).

Acetylcholine was found to be present in the chick embryo as early as 2½ days of incubation. The production of acetylcholine in the tissues increased from 2½ to 4 days of incubation, but thereafter to the 12th day the production fluctuated irregularly and the amount of variation was relatively small. No positive correlation was found between the development of acetylcholine and the development of reflexes or the development of the nervous system. The bearing of the results on the theory of chemical transmission is considered, and it is concluded that in the case of the chick embryo acetylcholine cannot be regarded as a chemical mediator in neural activities.

- (9) *The effects of voluntary changes in breathing on human respiratory exchange*. Thorne M. Carpenter. Cooperation in research, Carnegie Inst. Wash. Pub. No. 501, pp. 425-433 (1938).

The respiratory exchange of a man, post-absorptive, was measured during normal breathing, during abnormal breathing when the subject either breathed more deeply than usual or held the breath at intervals, and during the recovery period. Overventilation of the lungs caused marked increases in carbon dioxide elimination, oxygen absorption, respiratory quotient, and total ventilation, and a lower alveolar carbon dioxide. Under-ventilation caused marked decreases in all

these factors except alveolar carbon dioxide. The respiration rate was not seriously affected. The human organism requires a significant amount of time for readjustment and compensation when changes are produced in the equilibrium of its gases by voluntary over- or underventilation of the lungs. Alterations in breathing comparable to these voluntary acts are produced by emotional states and slight activity. Knowledge of the effects of changes in breathing on the respiratory exchange is an aid in interpretation of the respiratory quotient, which is an index of the kind of food burned in the body and the rapidity with which the combustion changes from one type of substance to another.

- (10) *Tables, factors, and formulas for computing respiratory exchange and biological transformations of energy*. Thorne M. Carpenter. Carnegie Inst. Wash. Pub. No. 303B. 3d ed. 142 pp., 44 tables. (1939).

To aid metabolism investigators in the calculation of results from data obtained with the various forms of respiration apparatus used with animals and man, this compilation of tables, factors, and formulas was first issued in 1921 (Publication No. 303). In 1924, as the supply of the first edition had been exhausted, a second edition (Publication No. 303A) was published by the planographic process. When this edition was exhausted, this third edition was prepared, also by the planographic process, to meet the continued requests for copies of the book. In this third edition two tables have been revised and seven tables have been added. The additional tables include the values for body surfaces (calculated from the Du Bois height-weight formula) of humans for weights from 40 to 110 kg., the Mayo Foundation prediction standards for humans, the Talbot prediction standards for children, and the energy cost of various activities.

- (11) *Human direct and indirect calorimetry with sugars*. Thorne M. Carpenter and Edward H. Bensley. Amer. Jour. Physiol., vol. 126, p. P459 (1939).

Abstract. (See page 211.)

- (12) *Lantern slides from typewritten material*. Thorne M. Carpenter. Science, vol. 89, p. 372 (1939).

Tabular and text matter are typed through white carbon paper on black paper, the rib-

bon indicator on the typewriter being set for stencil cutting. Photographing of such typed matter avoids the necessity of making lantern slide positives after the negatives are made.

- (13) *The food of the present-day Navajo Indians of New Mexico and Arizona.* Thorne M. Carpenter and Morris Steggerda. Jour. Nutrition, vol. 18, pp. 297-305 (1939).

The diet of the Navajo Indian consists principally of meat (goat and sheep), in contrast with that of the Maya Indian of Yucatan, which is predominantly corn. Practically all parts of the animal are eaten, including most of the alimentary canal. The weekly food consumption of the average Navajo family (6 or 7 people) consists of

one goat, about 10 kg. of flour, 2.5 kg. of white sugar, 1 kg. of coffee, and such vegetables as may be available. Analyses were made of the fat, nitrogen, moisture, and energy content of 66 samples of the commonest foods in the daily diet of these Indians. These included their corn flour, breads, mush, vegetables, fruits, nuts, berries, seeds, weeds, and meats. The fat and the nitrogen content of the different foods varied considerably, but the energy content was in most instances relatively constant between 3.5 and 4.5 calories per gram of air-dry matter. The meats and some of the berries and seeds, which contained higher percentages of fat, had energy values as high as 6 to 9 calories per gram.

TORTUGAS LABORATORY

D. H. TENNENT, EXECUTIVE OFFICER
PAUL S. CONGER, ASSISTANT EXECUTIVE OFFICER

During the summer of 1939 the Tortugas Laboratory was open from June 1 to August 8.

The following investigators studied at the Laboratory during the season:

- Alan Boyden, Bureau of Biological Research, Rutgers University. Collection of blood serum for serological study of relationship of invertebrates. June 1 to June 27.
- W. E. Bullington, Randolph-Macon College. Studies on ciliates of the Tortugas region. Spiraling in *Oscillatoria*. June 29 to August 8.
- Leonard B. Clark, Union College. Swarming of the Atlantic palolo. The effect of light on regeneration of sabellids. June 17 to July 25.
- Paul S. Conger, Carnegie Institution of Washington. Investigations on diatoms. June 1 to August 8.
- B. R. Coonfield, Brooklyn College. Color changes in marine fishes. Regeneration in embryos of the nurse shark. Effect of light on the hatching time of embryos of *Pomacentrus leucostictus*. June 17 to August 8.
- William L. Doyle, Bryn Mawr College. Studies on zooxanthellae. Enzymatic and biochemical studies on *Valonia*. Localization of amylase in amphioxus. June 1 to July 25.
- Ernest Hartman, College of Medicine, University of Vermont. Ecology of amphioxus. Studies on protozoan blood parasites of marine fishes. June 29 to August 8.
- Walter N. Hess, Hamilton College. Swarming of the Atlantic palolo. Study of the liver of decapod Crustacea. Molting in *Crangon armillatus*. Effect of light on the hatching time of the embryos of *Pomacentrus leucostictus*. June 17 to July 25.
- Gordon Marsh, State University of Iowa. The growth rate of *Valonia ventricosa*. June 1 to August 8.
- Vance Tartar, Yale University. Regeneration in the starfish *Linckia* and the ciliate *Condylostoma*. June 1 to June 27.
- D. H. Tennent, Bryn Mawr College. Continuation of studies on photodynamic action of dyes. June 17 to July 25.
- Ralph Wichterman, Temple University. Studies on ciliates in the Tortugas region. June 17 to July 25.
- Peter Grabicki, Union College, and George A. Streeter, Johns Hopkins Medical School, were research assistants at the Laboratory.

Of the twelve investigators working at the Laboratory, all but two were extending investigations begun at Tortugas in other years.

In providing material for Dr. Boyden's work the *Anton Dohrn* and her crew spent five days dredging in water up to 250 fathoms in depth. The material obtained was of value to Dr. Boyden, to other investigators at the Laboratory, and for comparison with collections of previous years. Some of the material collected was sent to the U. S. National Museum.

Dr. Bullington returned to his work on Tortugas ciliates, after an absence of several years, in order to complete and extend observations necessary to the preparation of a final report.

Dr. Clark and Dr. Hess continued their collaboration on a study of the swarming of the Atlantic palolo, a problem to which many investigators have given their efforts at Tortugas since the founding of the Laboratory. Their work has included a detailed experimental study of the effect of light on swarming as well as a prolonged survey of the swarming of palolo in different parts of the Tortugas region. Dr. Clark and Dr. Hess

also conducted independent investigations on the effect of light on various biological processes.

Mr. Conger continued the investigations on diatoms that he has made at Tortugas during several seasons. He studied collections made daily by towing and maintained in the laboratory throughout most of the season cultures started from two capsules of a form that regularly divides within oval-shaped capsules.

Dr. Coonfield continued work begun in 1938 on color changes in fish embryos and adults and on observations on the development of embryos of the nurse shark. He also collaborated with Dr. Hess in a study of the effect of light on the hatching time of *Pomacentrus* embryos.

Dr. Doyle completed research begun at Tortugas in 1934 and continued in 1935 on zooxanthellae occurring in foraminifera and coelenterates. He also made studies on the cytology of *Valonia*, on the distribution of enzymes in this organism, and on the distribution of amylase in amphioxus.

Dr. Hartman, who worked at Tortugas for the first time, brought to the Laboratory the benefit of his experience in the amphioxus fisheries of Amoy, China. He used the Chinese methods of collection and found it possible to collect amphioxus in considerable abundance. He found that spawning was occurring at Tortugas between July 26 and 29, which is almost the same date as at Amoy in 1930.

Dr. Marsh continued his physiological work on *Valonia*, studying particularly the relation of the protoplasmic E.M.F. in the light and in the dark to the pH of the medium, the potassium concentration, etc.

Dr. Tartar continued studies begun in 1938 on regeneration in *Linckia*, a starfish able to regenerate a whole animal from an arm segment which may be only a twentieth part of the original animal, and on regeneration in the ciliate *Condyllostoma*. He found that in *Linckia* the regeneration blastema always appears in close association with the radial canal. From his work on *Condyllostoma* Dr. Tartar has concluded that the presence of the macronucleus is necessary for the completion of cytoplasmic differentiation, a condition unlike that in the single-celled mononucleate alga *Acetabularia*.

Dr. Tennent continued his work on the photodynamic effect of vital dyes on the eggs of the sea urchin, begun in 1935. Of 15 dyes not previously used in this work at Tortugas, 3 were found to be strikingly effective. These dyes were Magdala Red echt, Phloxine, and Phloxine Red. Two vegetable dyes, chosen with the possibility in mind that they might contain a photosensitizing substance, were found to be ineffective in the concentrations used. These dyes were Madder and Purpurine-Madder.

Dr. Wichterman, a guest at the Laboratory for the first time, examined many animals for parasitic protozoa and found three new intestinal ciliates in *Pontodrilus bermudensis*, a marine earthworm of the intertidal zone of Loggerhead Key.

SEROLOGICAL STUDY OF THE RELATIONSHIPS OF SOME COMMON INVERTEBRATA

ALAN BOYDEN

A new impetus has been given to serological studies involving precipitation by the recent development of the photoreflectometer by Raymond Libby. This

instrument uses a photoelectric cell for the measurement of the turbidities resulting from the interaction of a precipitating antiserum with its homologous

and heterologous antigens. It has proved to be more accurate and more suitable for the serological comparison of the sera of related species than any other device, and gives more significant results than the ring tests used heretofore.

The results of testing an antiserum prepared in a rabbit by the injection of the native serum of *Callinectes sapidus*, with native *Callinectes sapidus*, *Carcinus maenas*, and *Cancer borealis* sera in

cinus maenas, a related genus belonging to the same family, 44 per cent and (2) *Cancer borealis*, which belongs to a different family, 14 per cent. These values appear to represent the similarities in the native sera of these species in a satisfactory way, and could be used directly, along with the usual morphological data, in systematic grouping.

There is increasing evidence that the quality of the serum proteins is a relatively conservative quantitative hereditary trait and well represents the entire organism. This is true because the serum penetrates all parts of an animal and must be in harmony with all its tissues. Consequently sudden changes in the quality of the serum would probably be lethal.

The development of the photoneflectometer has made it possible to adopt a new technique for serological comparisons which involves (1) the testing of each antiserum, so far as possible, with closely related species and hybrids of known genetic relationship, followed by (2) the testing of such antisera with sera from species of more distant, and more uncertain, genetic relationship.

For example, an anti-horse serum will distinguish between horse, mule, and ass, and the reciprocal anti-ass tests give the same distinctions. Furthermore, mule serum is between the two parent species but much nearer the horse. Antisera with such results, where known genetic relationships are involved, may then be applied with confidence to more distantly related species of more doubtful genetic relationships. In the case of the Crustacea, which are being studied in this way and which have been collected mainly at Tortugas, closely related species of the same genera will serve as the standard of reference for each antiserum wherever they are available. With such procedures the serological studies of animal relationships should reach new and higher levels of usefulness in taxonomy.

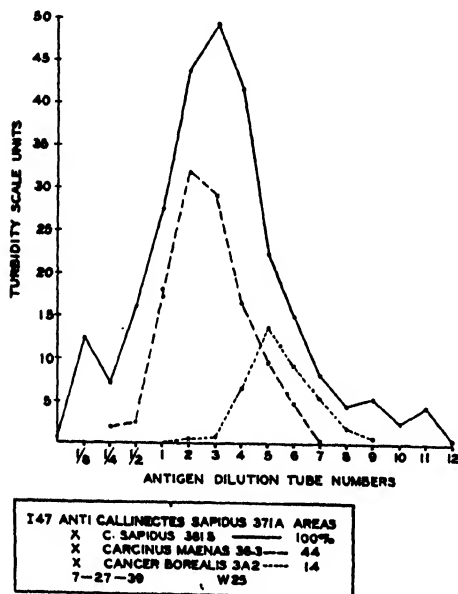


FIG. 1. The results of testing an anti-*Callinectes sapidus* serum with itself and with the sera of *Carcinus maenas* and *Cancer borealis*, with the photoneflectometer. All sera were native and are equivalent as to total protein. The turbidity in terms of scale units is shown on the ordinate; the dilutions of antigens used increase along the abscissa. Tube 1 represents a dilution of 1 part of protein in 500 parts of saline; each tube with higher number is twice the dilution of its predecessor.

equivalent amounts are shown in figure 1. It is believed that the relative areas under each curve best represent the total quantity of reaction of an antiserum with various antigens. Considering the homologous reaction as 100 per cent, the relative intensities for the heterologous antigens are (1) *Car-*

A PRELIMINARY REPORT ON SOME CILIATES OF THE TORTUGAS REGION

W. E. BULLINGTON

During the summers of 1930 and 1931, while making a special study of spiraling in certain species of ciliates at Tortugas, the writer found several which appeared to be undescribed, but owing to insufficient information they could not be identified. Again during the summer of 1935 some of these, and others not previously seen, were found. A few of those previously seen were identified, but for the most part necessary information was still lacking.

During the summer of 1939, therefore, another trip was made to Tortugas for the distinct purpose of restudying as many of these ciliates as possible, and any others which might present themselves, with the idea of publishing them in a paper under the title "Some ciliates of the Tortugas region." Many of these were found and a fairly complete study was made of them, but at the same time others not previously seen were added to the old list, so that there are still many concerning which information is not sufficient to permit identification or description. Further study of these is, therefore, necessary.

Two of those studied this summer are of sufficient interest to mention here.

An extremely large species of *Nassula*, found near the tip of Bush Key in 1931 but unidentified at that time, was found this summer in the bottom of the moat on the south side of Fort Jefferson on some of the algae. This species is very dark brown, almost black, is extremely large, measuring from 451 to 624 micra in length, and was mistaken in 1931 for the larval form of some marine worm.

The second, an unusual form which has the characteristics of both a heterotrichous and a hypotrichous ciliate, but which can be classified as neither, was found this summer for the first time. This one is almost cylindrical in form and rather short, measuring approximately 104 micra in length by 71 to 81 micra in width, and has ventral cirri like those of a hypotrich and oral cilia very much like those of *Condylostoma* (heterotrich). Only one species in any way corresponding to this seems to have been seen before. It is one given by Kahl (1932) as reported by Lepsi (1928) under the name *Gastrocirrhus intermedius*. But his is supposed to be flattened, whereas this is cylindrical, and his has a different arrangement of ventral cirri.

SPIRALING IN OSCILLATORIA

W. E. BULLINGTON

There appeared in one of the writer's salt-water watch-glass cultures at Tortugas a mass of *Oscillatoria* in which practically every segment of the plant was distinctly spiraled. Since no spiraling in any previously observed *Oscillatoria* had been seen, and no report of any by other investigators is known, it was believed of sufficient interest to report here.

In every case the spiraling was to the left. The number of spirals to a segment varied as the length of the segment. Some short segments had only one spiral; others, longer, had several. The spirals themselves varied considerably in length. Some measured only 441 micra, others measured as much as 954 micra. Most spirals, however, measured approximately 630 micra in length.

These spirals were not permanent, however, for a few days later in that same mass, very few spirals could be found. No reason is known why these plants should assume a spiral form one

day and lose it later. Trees and vines which grow in spirals do not lose their spiral once it is started, but rather tend to increase it. This is particularly true in trees.

THE PHYSIOLOGICAL ACTION OF VISIBLE LIGHT

LEONARD B. CLARK

With special apparatus it was possible to radiate animals with high intensities of artificial light. Sabellid worms were not injured by exposures up to 150 minutes with 11,000 foot-candles, but with an intensity of 13,900 foot-candles 50 per cent of the worms were injured by exposures of 40 minutes so that they died in 24 hours, and all were injured by exposures of 80 minutes. Radiation with

light of 20,000 foot-candles caused death within 24 hours to 50 per cent of the worms after 28.5 minutes' exposure and to all after 60 minutes. Although the temperature rose during exposure, worms exposed for 150 minutes to temperatures 2° C higher than the maximum recorded from the experimental chamber showed no injury.

THE ATLANTIC PALOLO

LEONARD B. CLARK

In eleven experiments, a continuation of work noted in 1937 and 1938 (Year Books Nos. 36 [1936-1937] and 37 [1937-1938]) on the effect of light on swarming in the Atlantic palolo, it was shown that light is a necessary factor, and that disturbance of the natural cycle shown by moonlight resulted in disturb-

ance of the time of swarming. Special emphasis was placed on the effect of the regular alternation of the dark and complete light (full moon) phase and of the regular alternation of the phases on swarming. It was shown that slight disturbances of either will result in delayed swarming over the controls.

SWARMING OF THE ATLANTIC PALOLO

LEONARD B. CLARK AND WALTER N. HESS

Systematic daily tows and observations from June 20 to July 24, 1939, showed that: (a) no large swarm occurred over West Loggerhead Reef during the summer, although small numbers of eggs were found on June 22, 23, 24, 27, 28, 29, July 1, 2, 4, 5, 9, 10, 11, 13, 19, 20, and 21, with a greater abundance on June 30, July 12, and July 14; (b) over Bird Key Reef eggs were secured daily from June 23 to July 20 with the exception of July 3, 8, 16, 17, and 18.

Eggs were abundant on July 2 and 5 and very abundant on July 6. The full moon occurred on June 2 and July 1; the third quarter, June 10 and July 9; new moon, June 17 and July 16; and the first quarter, June 24 and July 23.

These records are noteworthy in showing that the Atlantic palolo may swarm at or near each of the moon's phases except at the time of the new moon. Comparison with records of weather conditions showed a correlation between

preceding periods of calm and number of eggs recovered.

Efforts were made to follow the course of a swarm during the third quarter

moon, but only incidental observations could be made. However, it was determined that epitokes appear as early as 8:45-9:15 p. m.

DIATOM INVESTIGATIONS

PAUL S. CONGER

Studies of the morphology of a new species of *Amphora*, especially fine for showing the mechanism of vegetative reproduction, were continued as a major project of the summer's work, and drawings were made of several different views each of a number of stages in the reproduction of this diatom.

Further studies were also made on the movement of diatoms, and evidence was obtained for a new theory of diatom movement, which the writer feels is strongly supported by the facts observed.

Opportunity was afforded, in the course of several days of deep-water dredging work in the Florida Straits, for an attempted determination of the depth at which diatom life may occur, it being thought that in the very clear waters of this region, where light may penetrate more deeply than in turbid northern waters, diatom life might possibly occur at greater depths. All observations on this were, however, negative. In material from 18 stations, ranging in depth from 140 to 250 fathoms, some examined as soon as possible after collection, some preserved immediately in formalin, no recently living diatoms were recognized. This is a question on which very definite information is lacking.

Cultures were maintained throughout the summer of a small *Amphora* which regularly divides within oval-shaped capsules. Division proceeds until the capsule is filled with cells, when the lat-

ter are expelled and form new capsules. One culture dish with two capsules, started on June 12 with one capsule of 4 cells and one of 12 cells, contained on July 30, when it was stopped, seventeen capsules with a total of 126 cells. The capsules from extruded cells were smaller than the parent capsules. The content of cells in the final capsules was: one with 14, one with 12, six with 8, six with 6, and one with 4 cells. The secondary and tertiary capsules range in size from one-half to three-fourths as large as the original ones, and are more elliptical, and smooth in outline without protruding tubular ends. The figures conservatively represent only cells that could be distinctly counted, and it is likely that some of the capsules were lost in the sides of the dish or in periodic changes of water, a complete maximum quantitative growth not being attempted.

Some chemical tests were made to determine the nature of the material of these capsules, and of the stalks of *Licmophora*, suggesting pectin for the latter.

A new method was devised, and by it correlations were made of the natural living aspect of small obscure species of diatoms with their clean shells from which positive identifications could be made.

Additional studies were made of the silica relations in Florida marine waters.

COLOR CHANGE IN MARINE FISHES AND REGENERATION
IN THE NURSE SHARK

B. R. COONFIELD

The investigations discussed in this report deal with two problems. One is a study of color change. The materials used in this problem were fish embryos and adults and shrimp larvae. The other is a study of regeneration in shark embryos.

COLOR CHANGE IN MARINE FISHES

Embryos and larvae of *Pomacentrus leucostictus* were kept in both white and black bowls under a lamp while others were kept in a dark room during the observations. Some of the specimens were normal and others were eyeless. A preliminary study of the data shows that the embryos with eyes and under a lamp changed color to a very slight degree just before hatching. Those in the white bowls became pale while those in the black bowls were dark. Earlier in development and after hatching these young in white bowls were similar in tint to those in the black bowls. The embryos in the dark room showed a striking change in color just before hatching. These became extremely pale and remained in this color phase until after the hatching was complete. After this they became darker without any obvious response to different backgrounds. The eyeless specimens behaved in a manner similar to that of the normal ones.

The adult fish studied in regard to color change were the goby, *Bathygobius soporator*, and the burrfish, *Chilomycterus schoepfi*. Both of these fish were subjected to white and to black backgrounds under a lamp and some were kept in a dark room. Both normal and enucleated specimens were observed in this part of the investigation. The normal goby were pale with very small dark spots uniformly covering their

bodies when they were kept in a gray-bottom aquarium. When taken from this aquarium and placed in a white bowl under a lamp they became extremely light very quickly except for two dark bands encircling the body at the base of each dorsal fin. They retained this color pattern with only slight variations in the degree of lightness while being kept in these bowls for several hours. Specimens placed in the black bowls under a lamp changed to a very dark color. This color was due to large black spots distributed uniformly over the body. There was no indication of the encircling dark bands so conspicuous in this fish in white bowls. Those kept in a dark room for a few hours became quite pale. The enucleated ones were pale for two days after the operation, but following this period they became gradually darker until they were as dark as those with eyes subjected to the black background. These dark enucleated specimens became quite pale when they were kept in a dark room. They regained the dark color very soon after they were returned to an aquarium in light. These fish did not change their color when taken from the aquarium and placed either in white bowls or in black bowls.

The burrfish were subjected to the same experiments as were the goby. These burrfish were pale in white bowls and were dark in the black bowls under a lamp. They were pale while in a dark room. The enucleated ones in a dark room were pale, those in white bowls in light were dark, and those in black bowls in light were pale. These pale ones in the black bowls became dark when they were returned to the aquarium.

The larvae of *Crangon armillatus* possess only red chromatophores. These are distributed in pairs on the antennae,

eyes, cephalothorax, and abdomen. The chromatophores in normal larvae expanded in white bowls, contracted in the black bowls, and expanded in the dark room. The enucleated larvae showed contracted chromatophores while in white bowls and in black bowls under a lamp, and expanded ones when kept in a dark room. These changes in the chromatophores could be seen easily, since there were only a few of them over the body and since they could be observed clearly through a dissecting microscope.

REGENERATION IN THE NURSE SHARK

The experiments on the embryos of the nurse shark, *Ginglymostoma cirratum*, were concerned with regeneration following the removal of parts of the fins, and the cornea, iris, and lens of the eye. The results of these experiments are not available since each specimen must be prepared for histological study in order to ascertain the amount of regeneration that took place. It is important to note, however, a few points in regard to the methods employed in performing these operations and in keeping these experi-

mental animals living after the operations. The embryos inside of the intact eggs were rendered immobile by keeping them in bowls of sea water in a refrigerator at 8.5° C for about one hour. At the beginning of the operation a small area was cut out of the egg case to expose the embryo. During the cutting of the organ the specimen was held in the desired position with small curved forceps. Following the operation some of the embryos were allowed to remain in the egg case and were immersed in sea water. In some of these the original small hole was not enlarged, while in others most of the egg case was cut away. Some specimens were removed entirely from the egg cases and were kept in petri dishes in sea water. Some of the specimens were kept in the egg fluid and in a dark room or in subdued light. The best results were obtained by immersing the embryos in sea water and in the petri dishes in subdued light. Many of the specimens kept in direct light moved about so much that they injured themselves. They did not move about so much in the subdued light. A few of these survived 6 to 7 days after the operation.

CYTOLOGICAL AND BIOCHEMICAL STUDIES

WILLIAM L. DOYLE

ZOOXANTHELLAE

An investigation of the cytology of zooxanthellae occurring in foraminifera and coelenterates begun in 1934 and continued in 1935 (Year Book No. 34 [1934-1935], p. 79) was brought to completion. The following structures were observed: nucleus, cell wall, hyaline cytoplasm, plastid, amyloid grains, "assimilation product," oil droplets, pigment granules, and crystals of calcium oxalate. The occurrence and relative proportions of each of these constituents was found to vary under naturally occurring and experimentally produced conditions involving gas tensions and light intensities.

VALONIA

In a study of the distribution of enzymes in *Valonia*, further facts were gathered concerning the cytological structure of this organism. The dimensions of the cytoplasmic layer and of the cell wall were determined in relation to the volume and surface of the cells. The specific gravities of intact cells and various components were determined and these values were used to ascertain the time of origin of the central vacuole. A procedure for the determination of the distribution of enzymatic activity between the plastids and other portions of the cytoplasm was developed. Further

studies on material from the Tortugas Laboratory are being carried out at Bryn Mawr College.

AMYLASE IN AMPHIOXUS

Through the courtesy of Dr. E. Hartman, living amphioxus were available for enzyme studies. The gut was removed and slit open longitudinally and the food

mass washed out. Various portions of the gut wall were tested for amylase activity. The hepatic caecum was found to be the most active region, and the proximal portion of the intestine also showed marked amylolytic action. The amylase from both regions was most active at about pH 7.0. Further studies will be required to ascertain which cells produce the enzyme.

STUDIES ON THE HABITAT OF AMPHIOXUS AND ON PROTOZOAN BLOOD PARASITES OF MARINE FISHES

ERNEST HARTMAN

AMPHIOXUS

On the basis of the writer's experience at Amoy, China, with the amphioxus-fishing methods used by the Chinese and his observations on the habitat of amphioxus, an attempt was made to find amphioxus at Tortugas in numbers sufficient to permit experimental work to be done on them. With the aid of information about bottom and current conditions contributed by the group at Tortugas, the lancets were found at approximately north latitude $24^{\circ} 37' 30''$, west longitude $83^{\circ} 53' 4''$ on the second day, and subsequent dredging yielded about fifty specimens per hour. A number of days were spent searching in other areas with no positive results except a very few small specimens on the lagoon side of the shoal at the north end of Loggerhead Key and inside the reef to the west of Loggerhead Light. A hoe type of dredge similar to that used by the Chinese was most effective in concentrating the amphioxus in the sand to be examined.

The factors which determine the location of amphioxus are: (1) a bar or reef which on the lee side will protect the bottom from the more violent storms; (2) a current or tide which is of suffi-

cient intensity and duration to remove mud and fine sand but not to remove all the detritus from the bottom; (3) a water temperature between the extremes of 15° and 30° C; (4) a sand or sand-shell bottom which is free from grass and other sessile growths and which does not pack so hard that the lancets cannot penetrate. Possibly another function of the current is the aeration of the water and the removal of most of the bacteria which by laboratory tests are deleterious to the amphioxus. In the Tortugas region at present these conditions (except no. 3) are not optimum and were found only in a narrow strip along the lagoon side of Bird Key Reef at depths of 3 to 8 feet, though good conditions may exist in other small areas at greater depths. Therefore the amphioxus are not nearly so numerous as at Amoy, China. The large amount of broken staghorn coral at Tortugas makes dredging difficult, and very small local areas can be dredged more successfully than places only a few feet away. The localization factors given above applied to the amphioxus areas at both Amoy and Tortugas and will be encountered most often in bays or lagoons at moderate depths (1 to 30 feet below mean low tide). It is the writer's opinion that factors (1), (2), and (3) are the

most important in the localization of amphioxus, and his experience that larger (older) specimens are to be found where conditions more nearly approach the optimum. The conclusions in regard to limiting factors should be useful in locating other amphioxus areas.

After leaving Tortugas on August 8, 1939, the writer tested the above conclusions at the mouth of Lemon Bay on the west coast of Florida, where amphioxus had previously been reported, and found the conditions more nearly optimum and the amphioxus more numerous. The finding of many small specimens in finer sand and less current paralleled the findings at Amoy.

PROTOZOAN PARASITES

Blood, spleen, and liver smears were made from 80 marine fish belonging to 13 species and were stained with tetrachrome and examined for protozoa. Three different protozoa were found in 3 species of fish. In the spleens of several others, melanin pigment was found, which would seem to indicate abnormal hemoglobin destruction possibly due to protozoa, but the protozoa have not been found. Material was collected for subsequent studies and identification.

The writer is grateful to the Bass Biological Laboratories, Englewood, Florida, for assistance in the dredging at Lemon Bay.

THE LIVER OF DECAPOD CRUSTACEA

WALTER N. HESS

A study of the fresh liver of *Crangon armillatus* and that of the spiny lobster, *Panulirus argus*, shows, in addition to the regular hepatic cells which contain fat and glycogen, numerous giant cells of a distinctly different type which show neither glycogen nor fat. Many of these giant cells are vacuolated, and in *Crangon* they often contain crystals. When the fresh tissue is stained with a dilute solution of neutral red, the giant cells take the stain, becoming reddish in color like the islet cells of the mammalian

pancreas, while the smaller hepatic cells stain very faintly like the acinar cells of the mammal.

The injection of pilocarpin, which causes profuse secretion of exocrine glands, causes the smaller hepatic cells to discharge their secretions, but the large giant cells are unchanged.

These data suggest that the giant cells are probably endocrine in function. A study is now being made of the nature of their secretion.

FACTORS INFLUENCING MOLTING IN THE CRUSTACEAN, CRANGON ARMILLATUS

WALTER N. HESS

When placed in finger bowls in the laboratory at Tortugas, *Crangon* exhibits a diurnal molting rhythm which begins at about 10:00 A.M., reaches its height at about 2:00 P.M., and ceases at about 5:00 P.M. Although there is considerable individual variation, the average period between molts requires about 12 days

during June and July. Data obtained by keeping animals in dark rooms, and also in incubators with a constant temperature of 33° C, in which part of the animals were illuminated only at night while others were in darkness all the time, suggests the following conclusions:

1. Light as used in these experiments,

varying from 10 to 150 foot-candles, has little effect on molting in these animals.

2. Temperature is a very important factor in causing the diurnal molting. High temperatures set in operation the factors causing molting, while low temperatures or a fall in temperature checks them.

3. Animals kept at a constant temperature of 33° C, which was about 3° above the average daily temperature, had the period between molts shortened by about 25 per cent.

4. Young animals molt more frequently than older animals.

5. Females carrying embryos do not molt, and males kept in close confinement with seeded females have their period between molts extended.

6. This suggests that at least two hormones are concerned with molting. One, which is probably similar to the molting hormone of insects, causes molting, and another, which appears to be liberated by the developing embryos, inhibits molting.

EFFECT OF LIGHT ON HATCHING TIME OF THE EMBRYOS OF *POMACENTRUS LEUCOSTICTUS*

WALTER N. HESS AND B. R. COONFIELD

Eggs of *Pomacentrus* in the blastoderm stage were placed in finger bowls containing sea water. Some of these bowls were painted black, some were painted white, and others were unpainted. The white and the black bowls were illuminated by a mazda lamp of 140 foot-candles from 8:00 A.M. to 10:00 P.M. daily. The clear finger bowls with developing embryos were kept in the dark room. All bowls were placed in running sea water, which served to maintain an approximately uniform temperature.

One lot of 300 developing eggs which were exposed to light in the white and

black bowls showed 90.2 per cent of hatching at the end of 120 hours. An equal number kept in the dark room showed only 58.4 per cent of hatching at the end of the same period. A very slight difference was observed in the hatching rate of the eggs in the painted bowls. Those in the black bowls developed slightly faster than those in the white bowls.

The data obtained in this study suggest that the developing embryos which were exposed to light utilized radiant energy which speeded up their hatching time.

THE GROWTH RATE OF *VALONIA VENTRICOSA*; RELATION OF THE PROTOPLASMIC E.M.F. TO pH OF MEDIUM, POTASSIUM CONCENTRATION, ETC.

GORDON MARSH

Healthy *Valonia* were punctured in sea water and the protoplasm separated from the cellulose wall by gentle rolling between the fingers. The resulting aplanospores varied in diameter from 6 to 150 micra; the majority were from 30 to 60 micra. They were transferred to culture slides (microscopic slides bored with

fifty to one hundred 2-mm. holes and cemented to other slides) and submerged in flowing sea water in diffuse light. Some 300 aplanospores were measured at intervals over a period of from 4 to 8 weeks with an ocular micrometer at a magnification giving about 3 micra per ocular division. The volume increase

plotted against initial diameter varies irregularly, as judged from a random sample of the data, owing principally to rhizoid formation. The rhizoid volume was ignored because of the great variability in size, shape, number, and time of appearance. The average volume increase of the aplanospores was about 2000 per cent over a period of 8 weeks. The original spherical shape was not maintained during growth, ellipsoid and slightly irregular solid figures being most common. Some mortality was observed. Loss by flotation occasionally occurred, but in general the aplanospores became fixed to the floor or wall even before the appearance of rhizoids.

One hundred twenty-nine small coenocytes from 0.1 to 4.0 mm. in diameter were isolated into Syracuse watch glasses. The sea water was changed daily. Measurements were made over an 8-week period with an ocular micrometer, or, for cells over 2.0 mm. in diameter, with a millimeter rule and hand lens. The two types of measurement made on the same cell differed by less than 5 per cent. The volume increase for this period plotted against initial diameter follows a fairly smooth curve, dropping from 6700 per cent for cells 0.16 mm. in diameter to an apparent asymptote at 1000 per cent for cells 4.0 mm. in diameter. The faster growth of the small cells as compared with those in the culture slides was in part due to better illumination.

Evidence was obtained that impaled cells discharging their inherent current through salt bridges connecting the artificial sap with the sea water increase in volume at a rate faster than that of unbridged impaled cells.

The time curve of potential upon illumination for cells whose potential is reversibly depressed by cyanide is normal in form, but of small magnitude. The same is true for the narcotic phase of the effect of ether. Illumination during the stimulation phase of ether pro-

duces an irregular response, the potential oscillating continuously about the level of the dark (stimulated) potential. The form of the time curve is thus a useful qualitative index of the "state" of the electromotive system.

The relation of the inherent E.M.F. in the light and in the dark to the pH of the surrounding sea water was determined, using the glass and the quinhydrone electrodes. The limits of tolerance lie between pH 4 and pH 10; the death point is sharp and of an all-or-none character, with no zone of injury. HCl and HNO₃ gave similar results on the acid side of the pH of sea water ($8.2 \pm$). With decreasing pH the steady potential changes little between 8.2 and 7, and drops rapidly below pH 6. The normal orientation of the potential is reversed below pH 5 and the outside may become 15 mv. positive to the inside. The potential curve for illuminated cells resembles that for cells in the dark, save that the fall below pH 6 is more rapid. The effect of light virtually disappears near pH 4, but the form of the light response is normal.

In sea water made alkaline with NaOH the dark potential changes slowly to pH 9, then undergoes a rapid increase to pH 10, reaching 20 to 25 mv. In the light the potential is nearly independent of pH, but shows characteristic irregularities. Alkaline KOH sea water produces a similar effect on the dark potential, save that the potential rises to values of the order of 80 mv. In the light the potential is changed little, if at all, until the pH reaches a value such that the dark potential exceeds that in light; beyond this point the behavior in light and dark is similar. As would be expected, the light response of cells in sea water made alkaline with either NaOH or KOH is irregular and oscillating and resembles that for the stimulation phase of ether. The difference between the effects of NaOH and KOH is due to

the cations; NaOH-KCl sea water produces an effect equivalent to that of KOH sea water of the same pH and potassium-ion concentration. The effects of potassium ion and of hydroxyl ion are roughly additive. The full curve of E.M.F. plotted against pH resembles the titration curve of a buffer, with the point of least effect lying near pH 8. The potential difference obviously is not a regular function of either potassium-ion concentration or the potassium-ion, hydroxyl-ion concentration product.

An artificial sea water of pH 8.2 was made following the analysis of Lipman (Papers from Tortugas Laboratory, vol. 26, Carnegie Institution of Washington Publication No. 391, pp. 249-257) with potassium substituted for sodium, and mixed in appropriate proportions with normal sea water. The increase in the

steady potential in potassium sea water over the potential in normal sea water was plotted against the potassium concentration for cells in darkness. The curve is somewhat similar to that obtained by Damon (Journal of General Physiology, vol. 16, pp. 375-395), but rises more rapidly from the base line, reaching a value of 50 mv. at 0.07 M, and appears to tend toward an asymptote considerably beyond 0.5 M (the highest concentration used). Between 0.01 M (normal sea water) and 0.02 M the curve is concave upward. The E.M.F. plotted against the logarithm of the potassium concentration is not a straight line, but a definitely sigmoid curve.

In addition, preliminary experiments were performed upon the relation of the protoplasmic potential to several other morphological and physical factors.

REGENERATION IN THE STARFISH LINCKIA AND THE CILIATE CONDYLOSTOMA

VANCE TARTAR

FATE OF ISOLATED TISSUES OF LINCKIA GUILDINGII

The starfish *Linckia* is able to regenerate a whole organism from an arm segment which may be only a twentieth part of the original animal. Such regeneration is remarkable in so complex an organism and suggests a certain plasticity of the constituent tissues. To determine whether cells of structures already differentiated in one direction are capable of further differentiation, tube feet were excised and placed in drops of filtered sea water. These preparations were compared with tube feet of *Linckia* which had been boiled before isolation into unboiled sea water, and with tube feet of a starfish (not yet identified) which is similar in size and shape to *Linckia* but which does not regenerate the whole organism from an arm segment.

The tube feet of both starfish are, in the

intact animal, white or light cream in color. Fully half of the living isolated tube feet of *Linckia* developed a conspicuous pigmentation which was the same shade of red as the dermis of this starfish. This pigmentation appeared on the surface of the cell mass resulting from a slight dissociation of the cells of the tube foot. Pigmentation never appeared in tube feet the cells of which were killed by boiling. Likewise, when the cut end of the tube foot healed over and a certain pressure, as indicated by a swelling, was maintained in the foot, the structure retained its integrity for several days and no pigmentation appeared until dissociation of the cells commenced.

More than half of the isolated tube feet of the other starfish, which cannot regenerate the whole from a small part, likewise exhibited a change in color; but this change appeared as a very faint pink

coloration at the center of the cell mass. The dermis of this star is dark purple.

The studies on *Linckia* suggest that the coloration developed is a true differentiation of the pigmentation typical of this species, and that a certain amount of dissociation of the cells of the original structure is necessary for the expression of the potentiality. In the other starfish the change in color is too faint to justify a similar suggestion at the present time; but the point can be made that the fate of isolated tissues of this species is different from that of *Linckia*, and its more limited performance in regeneration may be traceable to a restricted potency of the constituent cells.

REGENERATION IN LINCKIA AND CONDYLOSTOMA

An extension of work of the previous year on regeneration in *Linckia* revealed that the regeneration blastema always appears in association with the radial canal immediately above the ambulacral groove. This circumstance is clearly seen in arms cut off squarely; but it is more strikingly shown by arms cut diagonally from the aboral surface downward and proximally to the oral surface. Such cuts leave a slanting surface in which

the most terminal part is of aboral tissue which heals to form a knob, but a second, subterminal projection, the blastema, appears below it and in connection with the central canal.

Further studies of regeneration in the ciliate *Condylostoma* demonstrated conclusively that the presence of the macronucleus is necessary at every stage for cytoplasmic differentiation to go to completion. The moment the nucleus is removed from the cell all differentiation of new oral structures ceases, though the fragment may remain alive for four days.

When a partial section of the animal is made such that a part undergoing differentiation is connected with the macronucleate portion by only a thin protoplasmic bridge, differentiation also ceases. It thus appears that the contribution of the nucleus which is necessary for differentiation cannot pass across a fine protoplasmic connection. The circumstance is hence different from that of the formation of the cell wall in *Spirogyra*, in which such formation occurs in any fragment provided it be connected with the nucleus by a protoplasmic fiber, however tenuous. Further cases will, however, be needed firmly to establish this behavior in *Condylostoma*.

THE PHOTODYNAMIC EFFECT OF DYES ON THE EGGS OF LYTECHINUS VARIEGATUS

D. H. TENNENT

This work was in continuation of that reported in Year Books Nos. 34-37. Fourteen of the twenty dyes used were obtained from the Henry Phipps Institute through the kindness of Dr. Esmond R. Long. In the procedure, unfertilized eggs of the sea urchin *Lytechinus variegatus* were irradiated at controlled temperatures with sunlight or with artificial light, in sea-water solutions of dyes in various concentrations. The intensity of the light used was meas-

ured with a tested General Electric exposure meter. Immediately after irradiation the eggs were inseminated in the dye solutions. The subsequent development of the inseminated, irradiated eggs was checked against that in two controls, one a non-irradiated dye control and the other a straight sea-water control.

Magdala Red echt, Grüber, was used in 1:20,000, 1:40,000, 1:80,000, 1:140,000 and 1:160,000 solutions. In 1:20,000 solutions the irradiated eggs swelled until

the diameter of the swollen eggs became half again as long as that of the non-irradiated eggs. These eggs stained pink and the surface formed clear spherical blisters. In 1:140,000 solutions 3 hours after the end of 15-minute irradiation there was 100 per cent cytolysis. In 1:160,000 solutions there was pitting of the surface of irradiated eggs in up to 5 per cent and cytolysis in 70 per cent of the eggs, but very little formation of blebs.

The absorption maximum of this dye is close to that of Neutral Red. The effect of irradiation in Magdala Red echt is somewhat similar to that in solutions of Neutral Red, the difference being that with Magdala Red echt the eggs swell before producing blisters. A photographic record of cytolysis in this dye solution was made.

Neutral Red, Grübler, was used in 1:150,000 solutions. The effect of this dye was not so uniform as in solutions made with other lots of Grübler and with the National Aniline Neutral Red, reported previously. Comparative studies were made with various lots of dyes and an excellent photographic record of progressive stages of blister cytolysis was made.

Phloxine Red, Grübler, was used in 1:40,000 solution. No separated fertilization membranes were formed. Following both 10- and 15-minute irradiations there was ultimately complete cytolysis. The eggs swelled gradually, stained pink, then red, and formed blisters, some of the size of the egg.

Phloxine was used in 1:40,000 solution. Within 7 minutes after the end of 15-minute irradiation 10 per cent of the eggs were pitted and vacuolated. In some instances the vacuoles united. This vacuolization increased during the next 12 minutes to 15 per cent, and to 50 per cent during the next half-hour, the vacuoles having a pink color. During this time most of the eggs formed blisters of the Neutral Red type. Finally

all the irradiated eggs disintegrated. About 10 per cent of the non-irradiated eggs remained intact; the others disintegrated.

The difference in effect of Phloxine Red and Phloxine suggested that both be used on eggs from the same female. The results confirmed those on separate lots of eggs. Phloxine Red, in its action, behaved somewhat like a basic dye, while the action of Phloxine was clearly like that of an acid dye. A photographic record of the photodynamic effects of these two dyes was made.

Methylene Red, Badische, was used in 1:20,000 and 1:80,000 solutions. With both of these concentrations there was some precipitation in sea water. There was no development following insemination in either irradiated or non-irradiated dye solutions.

Anthracene Red, Elberfeld, was used in solutions of less than 1:20,000 strength. Fertilizations were poor in the irradiated solutions, 20 per cent of the eggs showing irregular cleavage, 80 per cent remaining undivided.

Resorcin Red, Badische, was used in 1:80,000 solution. Development to the pluteus stage was normal in non-irradiated solutions, while in irradiated solutions plasmolysis and destruction of the surface of the egg occurred.

Thio Indigo Red B, Kahlbaum, was used in solutions of somewhat less than 1:25,000 concentration. This dye showed little photodynamic effect. In irradiated eggs the fertilization membrane was not well separated, nevertheless cleavage and development to the pluteus stage was normal.

Thiazine Red, Grübler, was used in 1:20,000 solution. Fertilization membranes were not separated in either irradiated or non-irradiated eggs. There was no development in any of the cultures.

Phloroglucin-Trypan Red was used in 1:40,000 and 1:80,000 solutions. In

1:40,000 solutions fertilization membranes were not separated in either the non-irradiated or the irradiated cultures. In the 1:80,000 solutions there was rare separation of fertilization membranes; about 1 per cent in non-irradiated dye solutions, but fewer following 15-minute irradiation (1 egg in several hundred). Cleavage took place in 3 per cent of the non-irradiated eggs and was exceedingly rare in irradiated eggs.

Oxamine Red B. N., Badische, was used in 1:40,000 solution. In both non-irradiated and irradiated solutions only about 5 per cent of the eggs formed separated fertilization membranes. The irradiated eggs formed lobular blebs, a solid core with a cortex of small vesicles of uniform size finally resulting.

Madder extract, Pickhart and Kuttrof, was only slightly soluble. It produced no effect in either irradiated or non-irradiated solutions.

Purpurine-Madder, Strohmeyer and

Lauth, was very slightly soluble. It produced no photodynamic effect.

Chrysoidin R, Grüber, was used in 1:50,000 solution. Well-separated fertilization membranes were formed on both non-irradiated and irradiated eggs. Cleavage was normal, but slower than in the sea-water control. Later development was also slow.

Salicine Red B, Kahlbaum, formed an excellent distilled-water solution which was not miscible with sea water.

All the photographic records mentioned above were made with the kind assistance of Dr. William L. Doyle. With his help photographic records were also made showing the photodynamic effect of Brilliant Green, from beginning lobular to complete colorless cytolysis, and of Eosin Y and Fluorescein, eggs in solutions of these dyes showing pitting of the surface and subsequent vacuolization of the egg, as has been described in a previous report.

INVESTIGATIONS ON THREE NEW CILIATES FROM THE LITTORAL EARTHWORM OF TORTUGAS

RALPH WICHTERMAN

While many animals were examined for parasitic protozoa, attention was mainly directed to the intestinal ciliates living in *Pontodrilus bermudensis* Belard, a remarkable marine earthworm of the intertidal zone of Loggerhead Key. The worms, which were very abundant, were found under partly covered windrows of decomposing eelgrass (*Cymodocea manatorum*) and turtle grass (*Thalassia testudinum*) from 2 to 15 cm. beneath the surface of the wet sand and at times very close to the water's edge.

Over 230 worms were dissected and a careful examination was made of the intestinal contents for protozoa. Of that number 64 per cent were infected with ciliates, all of which belong to three genera of the order Holotricha but which

appear to be new species. Brief diagnostic characteristics follow:

Hysterozineta n. sp. Found in 52 per cent of the worms examined. Size 137 by 55 micra. Cell body dorsoventrally flattened with dorsal surface slightly convex and ventral concave; anterior end tapering to a blunt point with posterior end widest and truncate; body very flexible. Sucker found ventrad on anterior end and shaped like an inverted V; cytostome and cytopharynx, which may be rudimentary, found on left side of extreme posterior end of body. Cytoplasmic inclusions resembling food vacuoles restricted to endoplasm at posterior end of body, but active feeding could not be seen even with Chinese ink and carmine. Contractile vacuole posterior and may have around it smaller accessory vacuoles. Body completely covered with cilia except for suckers; long, stiff,

curved cilia emanate from extreme posterior end. Macronucleus very long, measuring 77 by 14 micra; somewhat cylindrical in shape with tapering blunt ends and parallel to long axis of body. Conspicuous micronucleus in a depression on left side of center of macronucleus.

Anoplophrya n. sp. Found in 30 per cent of worms examined. Size 106 by 72 micra. Body broadly pyriform and slightly flattened with posterior end more pointed than anterior, where there is a thick, clear ectoplasmic band. Cell body completely covered with cilia; no attaching organ or mouth present. Contractile vacuoles generally 8 in number. Macronucleus very large and roughly triangular, measuring 54 by 24 micra and found in center of body with widest end anterior. Micronucleus has not been identified with certainty.

Maupasella n. sp. Found in only 4 per cent of worms examined. Size 72 by 25 micra. Slender and ellipsoidal in shape; ciliary lines prominent and cilia covering entire protozoon except for sharply pointed spinous fixing cell organ at anterior end of body. Contractile vacuoles generally 4 in

number, two being in middle and two posterior. Macronucleus very large, measuring 39 by 7 micra; cylindrical and in center of organism with long axis parallel to that of body. Micronucleus very small and found near center of macronucleus.

It is of interest to note that representatives of three genera of holotrichous ciliates are found in this marine earthworm, two of which are definitely astomatous and one, *Hysterocineteta*, possesses ingestatory structures which may be in the process of evolution toward the astomatous condition. Cysts and stages of nuclear reorganization and of conjugation were not observed. Acephaline gregarines and nematodes were observed, the latter in abundance.

A large number of prepared slides of dividing stages of all three species were made, and the details of fission and nuclear behavior as well as full descriptions of the ciliates with some experimental work will be included in the full paper.

DIVISION OF HISTORICAL RESEARCH¹

A. V. KIDDER, CHAIRMAN

The Division this year completes its first decade. It therefore seems appropriate briefly to review its activities during that period, and to consider the problems, scientific and administrative, which now confront it.

Three groups were brought together in 1929 to form the Division: archaeologists, students of United States history, and investigators of the history of science. As the latter, under leadership of Dr. Sarton, were engaged upon the definite task of producing the *Introduction to the history of science*, their activities continued unchanged. The staff of United States historians had been much depleted by retirements; further retirements were imminent. It having been at that time the Institution's policy to concentrate whenever possible upon researches of a type requiring cooperative effort, decision was made to combine resources available for documentary history with those of the archaeological group for a joint investigation in the Maya field.

The Maya Indians of Middle America developed the most brilliant culture of the pre-Columbian New World. Their achievements in sculpture, architecture, astronomy, mathematics, and hieroglyphic writing rivaled those of the great early civilizations of the Mediterranean; and although they had passed their peak before the coming of the Spaniards, they were still a numerous people. Today they form a majority of the population both of Yucatan and of Guatemala. The career of the Maya thus offers opportunity for study of several outstandingly

interesting phenomena: the rise of a civilization, the growth of a rich complex of the arts, the decay and fall of a culture, the impact of European conquerors on a native people, and the development of biracial communities typical of much of present-day Latin America. These are all of great significance, not only for the understanding of events in this hemisphere but for the light they can shed upon some of the most fundamentally important problems of anthropology and history.

The Institution entered the Maya field in 1914, through support of explorations by S. G. Morley, which during the next few years resulted in discovery of many new sites and in trebling the corpus of Maya hieroglyphic texts. On the basis of the dates contained in the inscriptions, Morley for the first time clearly delineated the major phases of Maya history: the Old Empire, during which Maya culture came into being and spread widely through the southern part of the Yucatan Peninsula and adjacent regions; the New Empire, centering in northern Yucatan, where an active renaissance resulted in the erection of such great cities as Chichen Itza and Uxmal; and finally, the period of invasion, civil war, and consequent decline which took place before the European Conquest.

Being largely based upon a series of bare dates and, for its later parts, upon more or less contradictory legends contained in native and Spanish chronicles, Morley's reconstruction of Maya history needed, he felt, to be checked by the shovel. Furthermore, only by archaeological means could a start be made toward clothing the chronological skeleton with the flesh of knowledge regarding the

¹ Address: 10 Friar's Place, Cambridge, Massachusetts.

ancient life and the arts of the Maya. He therefore selected for excavation three key sites. One of these was Uaxactun, a large ruined city in the Peten jungle of northern Guatemala, discovered by him in 1916; it was, on the basis of the hieroglyphic dates, the oldest and longest-inhabited Old Empire center. The second was Chichen Itza in northern Yucatan, settled about the close of the Old Empire, occupied through the renaissance, and a leading community, politically as well as ceremonially, during the latter part of the New Empire. The third, Tayasal on Lake Peten, also in northern Guatemala, saw the last stand of a Maya group against European encroachment. This city, founded toward the end of the New Empire by immigrants from northern Yucatan, remained unconquered until after 1690. Investigation of the three sites was designed to provide information regarding the Maya from the dawn to the final fall of their culture.

Work at Tayasal was carried on in 1920 and 1921 with satisfactory results; and in 1924 all available finances and personnel were concentrated upon excavations at Uaxactun and Chichen Itza.

Chichen Itza, because of its fine climate and ready accessibility, was made headquarters for research in Yucatan; and until 1935 excavations under Dr. Morley's direction were prosecuted there by E. H. Morris, K. Ruppert, J. S. Bolles, and others. The Temple of the Warriors was cleared, as well as the Caracol, Monjas, Mercado, House of the Phalli, and a number of smaller structures. These yielded a mass of data regarding the architecture, sculpture, fresco painting, and minor arts of the renaissance and the succeeding period when invasions from continental Mexico brought marked religious and cultural changes. All buildings investigated at Chichen were repaired, strengthened, and in some cases partially restored, in order that they

might stand as examples of the remarkable architectural achievements of the New Empire Maya.

At Uaxactun the work of O. G. Ricketson, Jr., and A. L. Smith, between 1924 and 1937, produced even more valuable results because, owing to the enormous difficulties presented by the Peten jungles and the great dilapidation of the ruins, relatively little had previously been learned of Old Empire archaeology. The first important discovery was of a very early building, elaborately decorated with colossal grotesque masks in stucco, buried under and perfectly preserved by a later pyramid. After this had been cleared, there were located below and in front of it still older deposits representing hitherto unknown formative stages of Maya civilization which had preceded the Old Empire and which exhibited suggestive relationships with the Archaic cultures of the Guatemalan and Mexican highlands. In 1931 A. L. Smith began his seven-year dissection of Structure A-V, which proved to have grown by successive additions and through several centuries from a group of small units to a great multi-chambered building of the "palace" type. In it were found tombs of various periods; from these and from the buried rooms and courts were collected vessels and potsherds exemplifying the entire course of Old Empire ceramic development, while study of the structure itself brought to light many facts regarding growth of and changes in architectural practice.

Uaxactun and Chichen Itza were richly productive of materials illustrating the arts and crafts of the Old and New Empires. Study of these materials raised, however, a host of new problems, for the most part concerning the chronological and spatial distribution, in other parts of the Maya area, of various cultural and esthetic traits made known by the two excavations. It thus became more and more clearly evident that the

archaeological findings, interesting as they were, could not be of maximum usefulness for reconstruction of Maya history until they could be interpreted in the light of knowledge regarding such environmental factors as geology, climate, water supply, and the faunal and floral resources of the country in which the Maya lived. Nor could ancient life or the ancient religion clearly be visualized solely on the basis of pottery and stone implements, sculptures, and the ruins of temples.

For the desired vitalization of the Maya's past, several nonarchaeological sources were available. One of these consisted of the Books of Chilam Balam, writings in the Maya language but in Spanish script, produced by native priests. They embodied histories, prayers, folk stories, medical lore; and they were, at least in part, translations of pre-Columbian hieroglyphic texts. Another rich store of information upon aboriginal conditions was contained in the eyewitness accounts of the conquerors, priests, and earlier colonial administrators. A third and extremely important body of information was to be had from the study of the several million Maya still living in Yucatan and Guatemala, speaking their old tongue, and practicing many of their former arts and even some of their aboriginal religious rites.

So when, in 1929, the organization of the Division led to review of its previous activities and to the making of plans for the future, it was decided to attempt a broader-gauge investigation in the Maya field. The first step in this direction was the addition to the staff of F. V. Scholes, to head a group for research upon the documentary history of the Maya; and of R. L. Roys, for the translation and interpretation of the Books of Chilam Balam and other native literature. At the same time, arrangements were made with the University of Chicago which

permitted the cooperation of R. Redfield for investigations among the present-day Maya.

Thus there were focused upon study of a single people the efforts of workers in the three major disciplines which deal with cultural and social evolution. Although such a joint attack by archaeologists, historians, and ethnologists had long been recognized as desirable, Carnegie Institution was the first to put it into effect with adequate resources and with prospect of being able to carry it forward for a sufficiently long period to determine whether or not it could produce the hoped-for results in factual knowledge, in historical interpretations, and, perhaps most important of all, in bringing about the close integration of the social sciences that is essential for real understanding of man's career.

Inaugurated in 1929, the cooperative research upon the Maya was broadened during the next few years in various ways. Study of the Maya group of languages was undertaken by M. J. Andrade; the Institution's Department of Genetics assigned M. Steggerda for work in physical anthropology, human geography, and nutrition; G. C. Shattuck of the Department of Tropical Medicine, Harvard School of Public Health, collected data upon health conditions in Yucatan and Guatemala; J. H. Kempton and the late G. W. Collins of the Bureau of Plant Industry, U. S. Department of Agriculture, R. A. Emerson of Cornell University, and W. Popenoe of the United Fruit Company have made explorations and laboratory studies bearing on the difficult problem of maize origins, as well as agronomic observations in highland and lowland regions. In the all-important matter of physical and biological environment much research has been done: in geology by C. W. Cooke of the U. S. Geological Survey; in climatology by R. G. Stone of Harvard's Blue Hill Observatory; in geography by W.

and R. A. Atwood of Clark University and the University of Florida; and the University of Michigan has cooperated most effectively by sending to Central America many specialists in zoology, botany, and tropical ecology. A. S. Pearse of Duke University has studied the fauna of the inland waters of Yucatan.

The above researches have been carried on through the thirties. During that period the Division's archaeological activities have to a certain extent been reoriented, in that emphasis has shifted from large-scale excavations at single sites to surveys designed to extend knowledge of the development and distribution of various elements of Maya culture. Thus, K. Ruppert and J. E. S. Thompson have gathered architectural data and hieroglyphic material from hitherto unknown areas lying between Peten and northern Yucatan; H. E. D. Pollock and H. B. Roberts devoted several seasons to New Empire ruins other than Chichen Itza, working on architecture and ceramics; R. E. Smith studied the pottery of Uaxactun; and Anna O. Shepard was added to the Division staff for work upon the physical and chemical properties of Maya pottery. F. B. Richardson undertook a comparative survey of sculpture in stone.

Digging, however, continued: at Chichen Itza until 1935, and at Uaxactun until 1937; and at Copan in Honduras, one of the greatest of Old Empire cities, G. Strömsvik has directed the excavations and the repairs of temples and monuments made possible by the aid of the Carnegie Corporation and the Honduran Government. J. E. S. Thompson has excavated in British Honduras; S. K. Lothrop, R. Wachope, and A. V. Kidder in the highlands of Guatemala.

The above activities, and the work of E. H. Morris upon the early stages of the Pueblo culture of southwestern United States, have resulted in such a flood of

new information that field work, during the past two or three years, has had to be curtailed to allow time for its digestion and for the preparation of reports. This pause has also given opportunity for review and appraisal of the program as a whole. Attempt has been made not only to judge the effectiveness of the Division as a fact-finding agency, but to determine to what extent its work in the Maya field is serving to develop methods for that coordination of the social, biological, and physical sciences without which it seems impossible to reach valid conclusions regarding the history of any people.

In the gathering of data the Division has been without question successful; and such study of results as has so far been possible indicates the direction in which various branches of the investigation should trend. In archaeology, for example, we must still further decentralize, devoting less of our resources to large excavations and more to small reconnaissance digs which will aid in delimiting the range of Maya culture and in determining its chronological and cultural relations with other Middle American civilizations. These minor excavations should be supplemented by comparative studies of certain categories of evidence which earlier work has shown to be of outstanding significance: pottery, architecture, sculpture, the hieroglyphic record. In documentary history we should attempt to fill the gap between the relatively well-understood Conquest and early Colonial periods and the present, because knowledge of what occurred during the eighteenth and nineteenth centuries is necessary as background for the ethnologists' studies of the modern Maya, and equally essential for the historian who wishes to utilize the ethnologists' results for understanding of times more remote. In ethnology, too, some decentralization would seem desirable, particularly in Guatemala, where,

conditions being less uniform than in Yucatan, a wider sampling would be profitable.

The enormous field of environmental studies has hardly been touched. On the biological side it is already clear that from the point of view of Maya history the botanical work is of great significance; and that more intimate knowledge of Middle American geology is needed for solution of many problems in ceramic technology, agronomy, water supply, and, in Guatemala, in the relation between volcanic activity and the ancient habitability of large sections of the country.

Materials are pouring in. We are learning what sorts of facts are of most immediate value. We are finding out where and how to get them. These are the easiest parts of the Division's task. Far harder is the interpretive synthesis which is the ultimate goal of the Division's researches, for each investigator is brought so quickly into virgin fields, is confronted with so great a body of intensely interesting and puzzling new material that he runs the constant danger of immersing himself in blindly intensive specialization. In the same way that the individual worker risks entanglement in detail, with indefinite postponement of the essential process of reaching conclusions, so the program as a whole may easily expand and ramify to such an extent that correlation becomes impossible.

The element of time must also be taken into account. The materials of Maya archaeology are practically inexhaustible. Profitable excavation could go on for a century. Environmental studies, in a region of such diverse topography and climate, might be continued indefinitely. Furthermore, one of our principal tasks is the gathering of information as to present-day conditions in Central America, undertaken to throw light upon the past, and also because the

region forms an ideal field for research upon problems of racial and cultural contacts which are of fundamental importance for the modern world. Here again, one perceives no halting place, for the present is always with us, change is constantly going on, significant new phenomena develop from year to year.

Our researches, accordingly, have no clearly discernible limit, either in space or in time. Certainly the project should be continued for several years. There are, as has been shown, certain known gaps in our knowledge which must be filled. However, there being no natural termination for our program, it has seemed desirable to adopt a policy of limited or, perhaps better, stated objectives and to establish approximate time schedules for the various units of research. When each investigation is brought to a close, all findings will be recorded, definite conclusions stated, and formulation made of problems for future attack. This arrangement should ensure that the older members of the staff will not reach retirement with unfinished work on their hands. For the younger men it should also be of benefit, as it is good for any student periodically to bring his research to a head, check up, draw conclusions, and make a fresh start. It is further believed that it would be well for the Division, toward the end of the coming decade, to attempt synthesis of the whole program by producing a history of the Maya based upon a correlation of all branches of the investigation.

The above proposed general stock-taking would permit ourselves and our colleagues to judge whether or not the project is so conceived and so prosecuted as to give promise of attaining the historical results for which it was undertaken. The conclusions which we then present should also enable the President and Trustees of the Institution to reach

decision as to the nature and scope of future activities in aboriginal American history.

There follows a summary of work ac-

complished between July 1, 1938 and June 30, 1939. Detailed reports by individual investigators are on file at the Division office.

ARCHAEOLOGY

As was the case in 1937-1938, field work in archaeology has been held to a minimum, in order that materials gathered in former seasons may be digested and reports upon them made ready for the press. During the year two of the Division's most important projects have thus been brought to completion: S. G. Morley's many years of research upon the hieroglyphic texts of the nuclear area of the Maya Old Empire through publication of his monumental work *The inscriptions of Peten*; and E. H. Morris' equally long-continued studies of ancient Pueblo culture, which have resulted in the monograph *Archaeological studies in the La Plata district, southwestern Colorado and northwestern New Mexico*, now in press. As was stated in the last Year Book, these two works will always rank as fundamentally significant contributions to the literature of their respective fields.

Notable progress has been made upon the reports dealing with the excavations carried on at Uaxactun between 1931 and 1937.² A. L. Smith, in charge of the Uaxactun Project, devoted the year to correlating the field notes, plans, and photographs, and to writing. In the task of presenting the extremely important results obtained in the complex of superimposed buildings constituting the "Palace," Mr. Smith has been most ably assisted by E. M. Shook, who worked with him throughout this difficult excavation. Mr. Shook is preparing the elaborate plans and sections necessary to make clear the growth of the "Palace."

R. E. Smith worked at the Guatemala office, where the specimens from Uaxactun are being studied prior to their deposition in the Guatemala National Museum. He has nearly completed the classification and description of the enormous and stratigraphically most valuable collection of pottery. He returned to Cambridge in the autumn to join A. L. Smith in assembling the final report upon Uaxactun. Miss Shepard, also, spent some months in Guatemala making technological observations upon the scores of thousands of sherds recovered at Uaxactun. Her collaboration with Mr. Smith not only has resulted in discovery of many significant facts regarding the pottery itself, but has made possible the development of methods for more effective cooperation between the field archaeologist and the ceramic technologist. The drawings and paintings of Uaxactun pottery have been made by Sr. A. Tejeda, staff artist, and Sr. Victor Lucas.

Dr. Pollock and Messrs. Thompson and Richardson spent the period under review in Cambridge, and Mr. Ruppert was there until he took the field in Mexico in the early winter of 1939.

Dr. Pollock worked on materials gathered during his architectural survey of the Puuc ruins of northern Yucatan. He has superintended Miss Ritchie's work in cataloguing and filing the Division's enormous collection of photographs; and while the Chairman was in the field, he administered the Division office.

Mr. Thompson completed and saw through the press a report upon the excavations at San José, British Honduras, and is now engaged upon a manu-

² The work of 1926-1931 has been covered by O. G. and E. B. Ricketson in Carnegie Inst. Wash. Pub. No. 477.

script dealing with the ruins of Benque Viejo, British Honduras. The technological aspects of the San José and Benque Viejo pottery have been studied by Miss Shepard.

Mr. Richardson, who is working on the stone sculpture of Middle America, has finished a paper based on his 1938 reconnaissance in Nicaragua, Salvador, Honduras, and Guatemala. He is at present preparing a summary of what little is known regarding the archaeology of western Honduras.

Mr. Ruppert made progress in assembling the data gathered during his several exploring expeditions to archaeologically unknown areas in Campeche, and also has under way reports on the Mercado, Sweat-bath, and other structures at Chichen Itza which were excavated by him.

Mr. Ricketson has also been at Cambridge throughout the year, continuing his examination of the scattered literature dealing with the geography of Middle America, and preparing a general work upon the physical and biological environment of the Maya area.

The above time-consuming but essential tasks have kept most of the archaeologists at their desks. A certain amount of field activity was nevertheless carried on, the most important of which was the work of Mr. Strómsvik and his assistants at the ruins of the Old Empire city of Copan in southwestern Honduras.

COPAN

The Copan Project, inaugurated in 1935 and jointly supported by the Government of Honduras and the Carnegie Corporation, has had two main objectives: the clearing and repair of buildings and monuments, and the gathering of detailed archaeological data. The former is primarily a task of conservation: to make available for present-day visitors and scholars and to preserve

for future generations the unrivaled architectural and sculptural treasures of this outstanding center of Old Empire civilization. The conservation work has naturally produced much new information regarding the antiquities of Copan, and various supplementary investigations have been made for the purpose of studying special aspects of the ancient culture.

For several miles up and down the narrow valley of the Copan River are mounds strewn with cut stone and fragments of sculpture. These remains of the city's minor temples cluster most thickly about the Acropolis, a central dominating structure built up generation after generation by successive additions and enlargements until it became a huge and lofty complex of temple-pyramids, terraces, stairways, and courts. On the Acropolis, in a great plaza adjoining it, and at various smaller groups in the valley, stood the intricately carved stone monuments so typical of the greater Old Empire cities. The stelae and their accompanying altars bear the hieroglyphic inscriptions, the partial decipherment of which has told us practically all we know regarding the astronomical and calendrical knowledge of the Maya. Those of Copan are numerous and exceptionally fine, but, like the richly sculptured temples before which they stood, the stelae had for the most part been thrown down and shattered by earthquakes and the impact of falling trees.

The first season at Copan was devoted largely to the assembling, mending, and re-erection of stelae. During the second, exploratory tunnels were driven into the Acropolis to determine whether or not complete buildings had been sealed beneath later accretions. This was often done by the Maya, but at Copan the tunnels proved that older temples were normally torn down before additions were made. Substructures, however, were

found to have been left intact and valuable data were recovered regarding their nature and the successive stages by which the Acropolis grew to its present enormous size. Also in the second year, there was begun the excavation and repair of Temple XXII. This was probably the finest and is certainly the best preserved of the culminating buildings on the Acropolis. Work upon it was finished in the third season, during which attention was also given to the consolidation of the great Hieroglyphic Stairway and the excavation of an interesting superposition of narrow courts in which an ancient ceremonial ball game had been played. The fourth year saw further work on the stairway and ball courts, but the major activity was the repair of a second temple, XI, together with the elaborate series of terraces leading up to it. From 1935 on there was a long struggle with the Copan River, which for centuries had been eating into the Acropolis. Finally, in 1937 Mr. Strómsvik succeeded in turning this seasonally rampant stream into a new course well away from the ruins.

Concurrently with the program of conservation there were carried on studies of architecture, sculpture, and pottery, which have yielded great amounts of data, intrinsically interesting and particularly useful for comparison with findings in other parts of the Maya area.

During the past season Mr. Strómsvik, assisted by S. Boggs, continued work on Temple XI, the most important discovery being that of a long, well-preserved hieroglyphic inscription flanking one of the temple's principal doorways. Mr. Strómsvik also undertook further repair of the Hieroglyphic Stairway, replacing a number of carved blocks of which the exact former position is unknown but which, lying scattered at the foot of the stairway, were exposed to serious damage. These stones are being set in such a way that future students

cannot confuse them with the steps actually found in place. In their present location they not only are safe from harm, but serve to restore to the stairway much of its original grandeur.

Miss Tatiana Proskouriakoff spent several weeks at Copan gathering materials for a series of drawings which will convey much more clearly and graphically than can be accomplished by any other method the probable appearance of the various buildings as they existed during the city's occupancy.

J. M. Longyear devoted a second field season to study of the pottery of Copan. In 1938 he had identified the major local types and had determined the succession of the principal ceramic periods. The present year, additional test pitting and trenching netted some 20,000 more potsherds. Among them are many of sufficient size to give better information than had previously been available regarding the shapes of vessels and their decoration. They also include a number of pieces of nonlocal manufacture which throw light upon chronological relations and trade contacts between Copan and other cultural centers both within and without the Maya area. Miss Shepard was at Copan in April to gain firsthand information as to archaeological and geological conditions in the valley, and to make preliminary technological observations on the pottery.

During the season the Government of Honduras constructed at the modern town of Copan a museum to house the pottery and other small specimens found in the excavations, and such finer pieces of sculpture as require protection from the weather. The museum building, erected under Mr. Strómsvik's supervision, contains exhibition halls, library, laboratory, and storage rooms.

VERACRUZ

A second activity carried on in cooperation with a Latin American government was the investigation of certain

archaeological sites in southern Veracruz. In this Mr. Ruppert participated with Lic. Juan Valenzuela and Ing. Agustín García Vega of the Mexican National Institute of Anthropology and History.

Veracruz has always been recognized as an area of much archaeological interest. The beautiful small stone carvings and the smiling pottery heads of the Totonac country are in many museums. Large sites are abundant. But neither local cultural sequences nor relationships with other parts of Middle America have been worked out. The latter, in particular, should be important, for there must have been contacts between this rich coastal belt and highland Mexico. Furthermore, southern Veracruz occupies a strategic position as regards migrations of peoples or cultures from Mexico into Yucatan. There are, as well, striking but as yet unexplained resemblances between certain Veracruz sculptures and those of Guatemala's Pacific coast plain.

When, therefore, the Mexican Government in 1938 proposed to the Institution a joint survey of the region, the invitation was gladly accepted and Mr. Ruppert was delegated to work with the above-mentioned Mexican archaeologists.

Two seasons have now been spent in southern Veracruz, attention having been directed to the general region of Los Tuxtlas. Excavation of numerous mounds has yielded interesting data on architecture, ceramics, and stone carvings. And while the collections, especially the pottery, have not been sufficiently studied to permit definite conclusions, there is indication of connections with Monte Alban in Oaxaca, Teotihuacan in the Valley of Mexico, the Huastec district of northern Veracruz, and Kaminaljuyu in the Guatemala highlands.

At the close of the field season in June,

Mr. Ruppert visited Tapachula, Chiapas, near the Guatemala border, to examine Izapa, a large and apparently important site containing a number of carved stone monuments.

GUATEMALA

Dr. Kidder spent the winter in Guatemala. Having finished, in 1938, the study of the nonpottery artifacts from Uaxactun and of the specimens from the Kaminaljuyu tombs, he was free to visit certain parts of Guatemala and Salvador which will sooner or later have to be investigated by the Division. A number of reconnaissance trips were accordingly made. At San Marcos in western Guatemala the collection recently made at Tajumulco by Miss Dutton of the School of American Research was studied; private collections in Quetzaltenango were seen. Dr. Kidder also visited the ruins of Zaculeu, near Huehuetenango, and large mound sites at Aguacatan and Zacapulas. He spent a few days with Dr. Mary Butler of the University of Pennsylvania Museum at her excavations in the very important Alta Verapaz district; and, after a trip to Copan, devoted ten days to a journey through the Republic of Salvador. That country literally teems with antiquities: sites are everywhere, and both in the capital and in the provinces are large, and in some cases well-documented, collections, the careful study of which would go far toward formulating for later attack by excavation certain very significant problems regarding the eastern extension of Maya culture and the relations between the Maya and the peoples of Salvador, Nicaragua, and Honduras.

CONTRACT WITH GOVERNMENT OF MEXICO

At the close of the field season Dr. Kidder joined Dr. Morley in Mexico City to arrange with Dr. Alfonso Caso, Director of the National Institute of

Anthropology and History, and Lic. Gonzalo Vásquez Vela, Secretary of Public Education, for a five-year renewal of the Institution's permit for research in Mexico, the former permit, which expired in 1937, having been extended for the single year 1938. This temporary extension was requested by the Institution in order to allow time for study of the whole Division program and, in particular, for consideration of the future status of Chichen Itza.

Since 1924 the Division's Mexican activities have centered about Chichen Itza. The Chichen hacienda served as headquarters for the ethnological work of Dr. Redfield's group, the medical research of Dr. Shattuck, the studies in physical anthropology, agronomy, and human geography of Dr. Steggerda, and for many other workers in history, linguistics, botany, and zoology. The many exploring expeditions in Yucatan and in the country to the south were based upon and equipped from Chichen. The large-scale excavations mentioned earlier in this report went forward there from 1924 to 1935. The activities fostered by Dr. Morley at Chichen Itza were directly responsible, indeed, for the conception and the later development of the broad program of Maya research now being carried on by the Division.

In the early thirties, however, it became evident that when the excavations then under way had been brought to a conclusion, we should know as much regarding the local antiquities as was, for the time at least, necessary; and that it would be desirable to halt operations at Chichen Itza and follow into other parts of the Peninsula various promising archaeological leads which had opened up. For this reason no major digging was done at Chichen Itza after 1933, and the next three years were devoted to study of the structures that had been cleared. The last actual excavation was done in 1936, and since that time, although the

hacienda has continued as headquarters for Dr. Morley and as a base for other workers, Chichen Itza has been of decreasing importance as a research center.

The rent and upkeep of the hacienda have been expensive and, since the opening of a motor road from Merida, there has been an increasingly serious drain upon Dr. Morley's time and energies for the entertainment of visitors. To discuss with Dr. Morley these problems and related matters bearing upon future work in Yucatan, President Bush and the Chairman visited Chichen Itza in February. It was then decided to give up the hacienda and establish a less costly and more central station in Merida. At the same time there were drafted proposals for the new contract which should be requested from the Mexican Government.

In May, these proposals were laid by Dr. Morley and the Chairman before Dr. Caso and the Secretary of Public Education, and a five-year contract was granted under which the Division is permitted to operate under most favorable conditions, but its obligated expenditure for field work is reduced from \$20,000 to \$6000 per annum. This reduction was desired for several reasons: first, because of the general financial stringency; second, because, the results of the Chichen Itza excavations being still not fully published, no new major projects can be undertaken for several years; and, third, because the work for the immediate future is planned to consist, for the most part, of relatively inexpensive, but highly important, reconnaissance surveys.

SOUTHWESTERN ARCHAEOLOGY

Returning to the scientific activities of the past year, there remains to be noted an archaeological project which, though not forming a direct part of the Maya investigation, bears a significant relation thereto in that it deals with aboriginal

American chronology and the rise of higher New World civilization. This is the work of E. H. Morris upon the early peoples of southwestern United States.

Knowledge of the Anasazi, or Basket Maker-Pueblo, culture of the Southwest has been more fully rounded out, by archaeological research on its early phases and ethnological study of its survivals, than that of any other of the many which ran their course in the Americas. The most primitive phase of the Anasazi so far reported upon reveals them as a people without domestic architecture, ignorant of pottery making, and without bow and arrow, using instead the atlatl or spear thrower. Still seminomadic, they were gaining an ever more sure foothold in the arid Four Corners region through the cultivation of maize, which afforded a controllable food supply and permitted increase in numbers. The coercion of corn growing soon made sedentary existence obligatory, and with the shift there came commensurate broadening of the range of material arts. Domestic architecture made its appearance and pottery began to be fashioned to take the place of the baskets and other woven containers that had been standard in the previous roving existence.

Thereafter development was extremely rapid. In what has proved to be a surprisingly brief lapse of centuries, the original one-roomed pole-and-mud dwellings had given way to enormous communal structures up to four stories high, containing a thousand rooms capable of housing two thousand people in a single dwelling. Social organization had been perfected to the extent that such a number could dwell in peace under one roof. Pottery making rose to the status of a fine art, with marked geographical specialization. Broadly viewed, a high order of agricultural civilization had been accomplished. Then, before the coming of the first Europeans, what

had been the cradle and homeland of the Anasazi was abandoned. As a result of the exodus there was concentration of population to the southeast, south, and west in those localities where the surviving Anasazi dwell today—along the Rio Grande, at Acoma, Zuni, and in the Hopi country.

Positive dating of Anasazi history was made possible by the tree-ring chronology perfected by A. E. Douglass. This medium has shown that in A.D. 475 the Anasazi had passed the beginnings of pottery making and were residing in single-room dwellings of poles and mud; that the great villages of Chaco Canyon, the peak of Anasazi architecture, were built between A.D. 900 and 1100; that the cliff dwellings of Mesa Verde were erected mainly in the 1200's, and that abandonment of the Four Corners country was complete by A.D. 1300.

While many details of Anasazi history subsequent to 475 remain to be worked out, the earlier stages are those which it is most important to reconstruct. It is here that a cave near Durango, Colorado, excavated by E. H. Morris during the summer of 1938, assumes its significance. This cave was occupied over an interval long enough to permit the accumulation of as much as 3 m. of refuse, and abandoned before the first experimentation with pottery making had begun. The inhabitants had broader skulls than comparably early Anasazi of other districts, a fact which suggests a possible difference in physical stock. They were more hunters than farmers, as is shown by the wide use of animal skins and a scarcity of the basketry and textiles so characteristic in other localities. Nevertheless, they did cultivate corn and pumpkins. They had no hafted axes or mauls, cutting and pounding having been accomplished with river-worn stones spalled sharp for the former, left rounding for the latter, held in the hand so that the arm served as a flexible

helve. They manufactured a wide range of chipped knife blades and projectile points and a profusion of bone tools. Their dwellings were single-roomed structures with saucer-shaped, mud-coated floors containing a firepit and one or more interior storage cists. There were also many storage cists adjacent to the living quarters. Aside from the basic fact that the walls and roofs of the dwellings were somehow compounded of small poles, twigs, and clay, the method of their construction has not been determined.

Quantities of charcoal lumps were recovered. None of them has as yet been positively dated, but the alignment of the evidence that their study at this time presents is extremely suggestive and, if confirmed, will be of great significance. The cave wood seems to fall into several well-confirmed floating series, each about 100 years long. These do not overlap, nor does one of them tie

into Douglass' central Pueblo chronology, which has been published back to A.D. 150. Either at one time tree growth in the vicinity deviated from what was normal for the northern Southwest, or occupation of the Durango cave was extremely early. The former is improbable, since timbers in the four, five, and six hundreds, as well as modern trees, fit readily into the central Pueblo pattern. Presumably, when the cave wood is finally dated, it will confirm the practice of house building and agriculture in the Durango district very early in, if not before, the Christian Era.

The remainder of the year Mr. Morris devoted to study of the materials from the Durango cave, to further work on basketry from northeastern Arizona, and to final revision of his report *Archaeological studies in the La Plata district, southwestern Colorado and northwestern New Mexico*. By July 1, 1939, he had resumed field work near Durango.

CERAMIC TECHNOLOGY

During the current year studies in ceramic technology by Miss Shepard were continued in both the Maya and the Southwestern fields; those in the Maya field were devoted largely to the Uaxactun collection and to general analyses of a preliminary nature, and those in the Southwestern field to specific problems outlined by earlier investigations, particularly firing methods, and paste composition of Rio Grande glaze wares.

The study of Maya pottery presents serious difficulties resulting on the one hand from limited knowledge of the distribution of types with consequent uncertainty regarding the source of foreign sherds, and on the other from the nature of the pottery itself, for both peculiar and ill-understood methods of manufacture and the extreme weathering which characterizes much of the material from

sites in the tropics makes accurate identification by visual inspection alone almost impossible. There are therefore decided advantages in introducing microscopic and other methods of analysis at the very inception of ceramic studies, as a means of ascertaining how peculiar effects in finish and decoration were obtained; while paste composition, which may constitute a basic criterion of classification, can always be accurately identified even in badly weathered material. Thus technological analysis furnished a sound basis for classification, as well as giving independent evidence bearing upon the relations of types and their sources. With these objects in view, pottery from sites excavated by the Division is being studied and the material supplemented by that from other collections, in order to build up our knowledge of the distribution of tech-

niques and materials. In the fall a petrographic study was made of the principal pottery types of Uaxactun and of a representative series of sherds from Copan, 178 thin sections having been prepared and analyzed. This work brings the collection of thin sections of Maya pottery to 655, including material from Peten sites, the highlands, Copan, and Chichen Itza. In addition to petrographic work, the sherd collection from Benque Viejo, British Honduras, was studied with the binocular microscope, paste composition and surface finish being compared with that of pottery from San José, British Honduras, and Uaxactun.

In the spring Miss Shepard spent two months in Guatemala in work on the Uaxactun collection. A total of over 10,000 sherds from stratigraphic tests was examined, and the tempering materials used in the various periods and wares are therefore now fully defined. The three main classes of tempering material (sherd, calcite, and tuff) which occur in the principal pottery types show a clear-cut chronological sequence and definite correlation with style and form. There is therefore every indication that temper will be an important means of learning sources of influence and the origins of imported pottery when distributions are better known. The value of the microscope for identifying intrusives, especially when surfaces are weathered, has also been fully demonstrated. Yucatan slate ware and eggshell orange from Mexico were both identified in this way. In addition to the analysis of paste composition, attention was also given to problems of surface finish and a microscopic study was made of the pigments of polychrome vessels. Certain pigments, particularly browns, grays, two flesh colors, pink, and purple, were found to be mixtures of basic pigments. This study will be carried farther to determine to what extent particular colors and

color techniques characterize pottery types and districts of manufacture.

Ten days were spent at Copan in the study of sherds obtained from stratigraphic tests. The basis of classification of this material was checked and a preliminary analysis made of paste and finish. A search was made for local sources of clay and temper, and samples of raw materials were collected for laboratory testing.

Work was continued by Miss Shepard in the Southwestern field during the year because, even though analytical work on Pueblo pottery was not immediately required by archaeologists of the Division, pottery made available through the work of other institutions afforded evidence on basic ceramic methods, thus contributing to the broader program for the study of the history of ceramic technique and for the refinement of methods of pottery study which has been outlined for the project.

The month of August 1938 was spent with the Peabody Museum expedition at Awatovi in the Hopi country, equipment for thermal tests as well as the microscopes and reagents for pigment analysis being taken into the field. In view of the fact that coal was used to fire pottery in prehistoric times in the Hopi district, a series of experiments was made in which juniper wood and coal were compared as fuels for pottery firing. Local clays were tested in these experiments in order to compare their firing properties with those of the ancient pottery and particularly to learn whether or not the sequence of gray, orange, and yellow in the dominant painted types was caused by a change in the kind of clay used, by the method of firing employed, or by both factors. Altogether over fifty plaques were made for clay and pigment tests, and eight experimental firings lasting from one to ten hours each. It proved much easier to obtain oxidizing conditions (the method of firing which

produces cream, buff, and red clay color) with coal than with wood, and particularly striking was the ease of maintaining temperature with the coal firing. Nevertheless, with short firing imperfectly oxidized bodies could be obtained, and likewise with juniper wood both oxidized and reduced bodies were obtained, depending upon the control of the fire after maximum temperature had been reached. These experiments elucidated questions regarding the control necessary in firing to produce wares showing different degrees of oxidation, a fundamental question in Pueblo ceramics.

Rio Grande glaze-decorated ware is one of the most favorable so far found for petrographic analysis because of the great variety of materials used and because our knowledge of the geology of the district enables us to trace the sources of materials. This ware therefore affords an opportunity to recover in great detail the history of the manufacture of the ware and the trade relations of the people using it. Petrographic studies had, however, previously been restricted to excavated material from a few sites. In order to extend our knowledge of the variety of materials used and their distribution, and to learn where more intensive work is desirable, sherds from the surface survey collection of the Laboratory of Anthropology, Santa Fe, were studied through the courtesy of Dr. Mekeel, director, and Dr. Mera, archaeologist of the Laboratory. Over 1500 sherds were examined and thirteen

different classes of tempering material recognized with the binocular microscope. The plotted results showed a marked change in the region of dominance during the life of glaze-decorated ware, and new evidence was obtained regarding the extent of the area in which it was made.

During the years in which technological researches have been conducted by the Division, Miss Shepard has consistently attempted to integrate this highly specialized aspect of pottery study with general ceramic investigation rather than allow it to become merely a means of performing a set of routine tests. Whenever analyses have been made, the questions raised have been considered in relation to general archaeological problems, and the results of analysis have as fully as possible been correlated with the results of the study of the stylistic features of pottery. During the past year the need for this close relation between the technological and archaeological work has become particularly evident in the Maya field, and in consequence a great amount of time has been given to a consideration of field problems and to the general methods of pottery study employed by the archaeologist. The questions which as a result of laboratory analysis are continually raised regarding the significance and accuracy of ceramic data, together with the availability of laboratory facilities, should materially aid in the improvement of general methods for ceramic study.

HISTORY OF YUCATAN

The Division's archaeological activities, already discussed, have added much to our knowledge of the Maya of ancient times. To carry their story another step farther is the task of the documentary historians. Their work has triple aims. One of these is to glean from native and

Spanish chronicles such information regarding the social, economic, and religious life of the Maya as will aid in explaining many puzzling aspects of the archaeological finds. The second, and this of course is in the historian's own province, is to reconstruct as fully as

possible the events which shaped the destiny of the Maya from the Conquest to the present day. The third is to erect for the ethnologists and other students of the living Maya the same sort of background that the archaeologist provides for the historian.

The Division entered the documentary field in 1931 with the appointment of F. V. Scholes. With him have since been associated R. S. Chamberlain, Eleanor B. Adams, and the Mexican scholar J. I. Rubio Mañé; while R. L. Roys has devoted himself to the translation and interpretation of the Maya's own literature, the so-called Books of Chilam Balam.

The history of the Maya from the period of the Spanish Conquest to the present time has a definite importance not only in relation to other phases of the Yucatan Project, but also for the general field of Latin American history. The significant problems of the history of those Latin American countries where the Indian has survived in any considerable numbers are essentially social problems. Latin America may be regarded as a laboratory in which vast cultural and sociological experiments have been carried out. Aboriginal civilizations, varying in achievement, flourished over a period of many centuries in several parts of the Latin American area. In the sixteenth century these civilizations were submitted to a rude shock by the European Conquest, but neither the Indian nor his culture was wholly destroyed. The Indian survived, and today Indian blood is a predominant strain in the population of many Latin American countries. Elements of aboriginal culture also survived in language and old folkways. To these have been added many characteristics of Hispanic culture. The four centuries since the Conquest have thus been characterized by a long process of fusion, conflict, and amalgamation, resulting in the evolution

of a Hispano-Indian civilization, varying with geographic conditions, the virility of the old Indian culture, and the policies and prowess of the conquering race. The survival of the Indian and of modified phases of his culture is the basis of many of the major modern Latin American problems of political and social significance, such as the distribution of wealth, land tenure, general economic progress, education, and public health. In recent years, moreover, the art and literature of Latin America, especially of Mexico, have been vitally affected by the same influence. The study of Latin American history is, therefore, essentially a study of the fusion and conflict of cultures. A sympathetic understanding of these processes is essential for any just estimate of contemporary Latin American life.

The sources for historical research upon the Maya are partly printed: accounts of the discovery and Conquest, histories of the Colonial period, and works dealing in a more general way with Spanish policy toward the Indians. But by far the greater amount of material still lies buried in the archives of Yucatan, Mexico City, and Guatemala, and particularly in the enormous repository of the Archive of the Indies at Seville. The word "buried" is used advisedly, for not only are the desired papers often difficult of access, but pertinent facts must be gleaned from countless thousands of manuscripts: records of the church and of the courts, tribute rolls, and the multitudinous reports of officials. From this mass of at first sight mostly sterile, routine stuff come not only solid factual data, but also flashing side lights which often illuminate the life and events of the times more clearly than do the pages of the formal histories.

A preliminary survey of the archives of Yucatan made by Mr. Scholes in 1931 revealed that a large part of the local papers, especially for the Colonial period,

had apparently been lost or destroyed. Consequently it was decided to postpone a detailed study of the local documents until considerable work had been done in the central archives of Spain and Mexico. Mr. Scholes and Dr. Chamberlain spent two and a half years (1932-1934) in Spain, and Dr. Chamberlain has also worked in the archives of Mexico City, Guatemala, and Salvador. In 1936 Sr. Rubio Mañé started a survey of the Yucatan materials in the Archivo General de la Nación in Mexico City. Photo-stats and Leica films of important documents relating to the Maya have been brought back for study. These are gradually being digested, materials of value to other scholars are passed on to them, and information is steadily accruing for the two major histories which will be produced by the Division: that of Yucatan by Mr. Scholes and that of the conquest of Central America by Dr. Chamberlain.

During the past year Sr. Rubio Mañé continued his investigations in the Archivo General de la Nación in Mexico City, and Miss Adams, who spent several months (July 1938—May 1939) in Mexico, also gave part of her time to research in the same archive. Most of the important *ramos*, or sections, open to investigators have now been searched for documents on the Colonial history of Yucatan. During the year 1939-1940 Sr. Rubio Mañé will assist in the cataloguing of a large section that heretofore has been closed to investigators, and it is expected that additional materials on the history of the province will be found in this collection.

The local Yucatan collections have not been entirely neglected, however, during the past eight years. In 1935-1936 Sr. Rubio Mañé made a survey of the Archivo de Protocolos in Merida and the parish records in Merida and Campeche. Mr. Roys and Sr. Rubio Mañé have also worked in the parish

archives of some of the Indian towns. During the summer of 1936 Dr. Chamberlain examined materials in the Biblioteca Cepeda and the Museo Arqueológico e Histórico in Merida.

In the Archivo de Protocolos in Merida, which contains registers of deeds, mortgages, wills, etc., nothing remains for the period prior to 1689. Beginning with the eighteenth century, however, this archive is fairly complete, and will be the source of much information concerning the economic history of Yucatan during the past two hundred years. The parish records of Merida have been preserved in almost complete form; those of Campeche, although less complete, are fairly extensive. These documents have little value, however, for the study of political and administrative history.

During February, March, and April of the past year Mr. Scholes, assisted by his nephew, Mr. W. V. Scholes, made a survey of the Archivo General del Estado and the documents in the Museo Arqueológico e Histórico in Merida.

The Archivo General del Estado contains several thousand bundles and volumes. These papers, formerly kept in the Museo Arqueológico e Histórico, have recently been transferred to another building and set up as a separate archive. At the time of Mr. Scholes' visit last spring the newly appointed custodian had not been able to begin the arduous task of classification, but permission to make a search for Colonial materials was granted. It was hoped that this collection—the official papers of the province and state of Yucatan—would contain local administrative documents of the Colonial governors and other local officers, especially for the sixteenth and seventeenth centuries, but this hope was not justified. Search by the Messrs. Scholes revealed only a very small amount of Colonial material, dating from the last half-century of the

Spanish period. One group of papers, however, is worthy of special notice, viz., an almost complete town-by-town census of the province for the years 1809-1811. These census reports and a few other documents were photographed. For the nineteenth century the collection is remarkably complete, with long series of administrative decrees, correspondence of local officials, special reports, journals of the local legislative bodies, vital statistics, etc. These materials will provide the documentary basis for the history of Yucatan since independence.

The Colonial archives of the *cabildo* of Merida are now kept in the Museo Arqueológico e Histórico. Unfortunately the documents of the sixteenth and seventeenth centuries have been lost or destroyed. The earliest *cabildo* books begin with the decade of the 1740's, and for the remainder of the Colonial period the series is fairly complete. The Museo is also custodian of an important collection of registers of military decrees, local correspondence, and other administrative papers for the last two decades of the Colonial period and the first half-century after independence. During the past spring photographs were obtained of a large part of the *cabildo* documents for the eighteenth century.

During the past spring inquiry was made concerning the archives of Valladolid. Only a few documents (all of recent times) were found in the Ayuntamiento, and it appears that the Colonial archives and most of the papers for the nineteenth century have been destroyed. There is also little hope of finding important early administrative documents in Campeche.

The fragmentary character of the local collections increases the importance of the Spanish and Mexican archives as the principal storehouses of documents on the Colonial history of Yucatan. We are also brought face to face with certain definite

problems. Some of the most important aspects of the Colonial history of the province, as of other parts of Spanish America, are those relating to Indian labor, land tenure, and the government of Indian towns. For these questions, local administrative documents would naturally constitute one of the principal sources of information. Unfortunately the major local collections that have been examined contain very little material of this kind for the sixteenth and seventeenth centuries. With regard to land tenure the gap can be filled in part by the hacienda papers in private hands, some of which go back to the sixteenth century. Mr. Scholes and Sr. Rubio Mañé have been permitted to examine and copy certain documents of this kind. During the past spring photographs were also obtained of a privately owned document of great historical value for the Calkini area. And there is always the possibility that some new collection of administrative papers may be found in Merida, although the fragmentary character of the archives that have been surveyed offers little hope that early documents have been preserved in considerable quantity. For many problems we must turn to the archives of Mexico, where early administrative papers for other parts of New Spain are available, and generalize, at least in part, on the basis of practice in these areas. Study of administrative practice in other areas would have been important in any case, in order to form valid conclusions concerning Yucatan problems and as a means of providing bases of comparison; for the history of Yucatan during the Colonial period must be projected against the background of general Spanish colonial policy and achievement. But in view of the present lack of early administrative documents available in Yucatan, this procedure has become a positive necessity.

To this end Mr. Scholes and his assist-

ant spent several weeks in Mexico City in May, June, and July, during which time investigations were carried on in the Archivo General de la Nación in collaboration with Sr. Rubio Mañé. Copies were made of numerous documents illustrating administrative practice in New Spain with regard to Indian labor, the functions of local Indian officials, land tenure, stock raising, local industries, the social status of Indians, mestizos, Negroes, etc.

During the past year two volumes of documents, edited by Mr. Scholes and Miss Adams, were published in Mexico City. These volumes, entitled *Don Diego Quijada, alcalde mayor de Yucatan, 1561-1565*, contain selected parts of the contemporary records of the investigation of idolatry made by Fray Diego de Landa in 1562, letters describing conditions in the province, documents on the problem of forced Indian labor, and official papers relating to the residencia of Quijada. A brief résumé of the idolatry proceedings was also embodied in a paper written by Mr. Scholes and Mr. Roys (see bibliography).

Conditions in Spain made it necessary for Dr. Chamberlain to postpone his trip to Seville to complete his investigations relating to the conquest of the Maya area. During the past year, therefore, he has carried on a series of lesser investigations. He has published a short study on the Castilian origins of the *encomienda* system and a paper on the concept of the *señor natural* in Spanish and Indian law (see bibliography). In February he gave a lecture in Washington on Spanish methods of colonization as illustrated by the history of Yucatan. The text of this lecture was published in the *Scientific Monthly* (see bibliography). At the end of the year 1938-1939 he was at work on a survey of pre-Conquest tribute systems.

In the autumn of 1938 Dr. Hanke resumed his investigations on theoretical aspects of Spanish colonial policy and

administration in the sixteenth century, after an interval of twenty months, during which he held appointment as research fellow of the Social Science Research Council. During the past spring he was appointed Director of the Hispanic Foundation of the Library of Congress.

During the period under review Dr. Morley and Mr. Roys have continued their research on the Xiu, the pre-Spanish lords of the great New Empire city of Uxmal, who retained for many years after the Conquest the status of nobles, and whose descendants are still living in Yucatan. The story of this family through the centuries illustrates, and in some ways epitomizes, the whole later career of the Yucatecan Maya.

Mr. Roys spent the late winter and the spring of 1939 in Yucatan working with Dr. Morley, gathering linguistic data, and, alone and in company with Mr. Scholes, visiting various parts of the Peninsula in order to locate and study the environmental conditions at a number of sites which were of importance during the Conquest and in the days of colonization.

From Motul, as headquarters, a number of towns were visited in the eastern portion of the former province of Ceh Pech. Like the western part of this province, the country around Chicxulub and Yaxkukul, which had previously been examined (see Year Book No. 36 [1936-1937], pp. 23-24), the rocky land is flat or slightly rolling and now given over to the cultivation of sisal hemp. Little maize is raised, and where it is, the production is low; so it seems not unlikely that the prosperity and thick population of this region at the time of the Conquest should be ascribed to salt production, fisheries, and commerce. There is a handsome Spanish Colonial church in every town, but unlike the western part of the province, where ruins are frequent, no pre-Spanish remains were seen except

at Uci, a short distance north of Motul. Here, from the top of the highest pyramid, seven other mounds, large and small, could be counted, and there are two cenotes in the center of the group.

A survey was also made of a part of the northern coast of the province of Ceh Pech. The site of Maxtunil, which figures prominently in the Pech papers and was a town of about 2500 inhabitants in 1549, could not be located; but the long, narrow lagoon inside the sand dunes was followed with considerable interest, as we believe it to have been an important commercial route in former times.

Mr. Roys also made a journey in search of the former town of Hunacti, the capital of what appears to have been a semi-independent subdivision of the Xiu state, but lying outside the province of Mani proper. It was governed by a member of the Xiu family, an intimate associate of the last Xiu ruler. This town figures in the Chumayel migration narrative, one of the Maya chronicles, the Mani land treaty of 1557, and Landa's inquisition proceedings in 1562, and then completely disappears from all the records. Inquiries during previous years at Tekax, Peto, and Tadziu had elicited no information, and it was decided to go to Tixmeuac and start from there in the direction indicated by the Chumayel narrative. No one at Tixmeuac had ever heard the name, but some 6 km. to the northeast a group of about fifteen platforms and pyramids and the ruins of a Spanish church were found. These are generally known as the ruins of Sisbic, but local Indian farmers stated that among themselves the place has always been called Hunacti.

From Tixmeuac a number of border sites of the province of Mani, mentioned in the treaty of 1557 and shown in the native maps, or diagrams, of the prov-

ince, were located and plotted. Several of these were found to be Maya ruins, which are fairly numerous in this region.

With Mr. Scholes a visit was made to Calotmul, which, together with Peto and Tzucacab, formed another semi-independent subdivision of the Xiu state. A site of this name near Catmis sugar plantation had been reported to Sr. Rubio Mañé. Catmis, when visited, was found to correspond to what we know of this Calotmul; there are several Calotmuls in Yucatan. Here, too, was found a Spanish church and cistern among a large group of ancient mounds.

The former site of Tixchel was also visited (see Year Book No. 36 [1936-1937], p. 155). It was situated on an estuary of Laguna de Términos and commanded the principal commercial route between Mexico and Yucatan in pre-Spanish times. The place figures prominently in the Paxbolon *relación* (see Year Book No. 33 [1933-1934], pp. 107-108; No. 34 [1934-1935], p. 147). The Chontal-speaking Acalans once lived here until driven out by their neighbors of Tabasco and Champoton; and their descendants resettled on the spot in the middle of the sixteenth century. A few mounds, one fairly large, were found on the shore of the estuary, while there is a slightly larger group about 4 km. inland. The two groups are connected by a paved road, which crosses the mangrove swamp lying between them, and it is difficult to determine which was the pre-Spanish Acalan town. The region is of interest, as it represents the northernmost extension of the Maya Chontal at the time of the Conquest. It is now Hispanicized, but a possibility exists that a few Chontal-speaking families were still living not far from Tixchel down to a generation ago.

SOCIOLOGY AND LINGUISTICS

Although the attention of the historians has naturally so far been focused largely upon the earlier phases of the post-Conquest period, their findings have cross-checked most interestingly with those of Dr. Redfield and his group, who, since 1930, have been observing and recording conditions among the living peoples of Yucatan and Guatemala.

At the time that arrangements were made with the University of Chicago for Dr. Redfield to devote some months each year to directing and taking part in the ethnological wing of the Division's program, he made it clear that the work (which began in Yucatan) must be guided by two primary assumptions. One assumption is that although the Institution's interest in the Peninsula had its beginning in connection with the ancient Maya, and although it is certain that study of the present-day Maya will throw light on the Indians of the times before the Conquest, nevertheless, the ultimate aims of science are more likely to be served if the student describes what is actually before him. If a student of society should report only what is apparently aboriginal, he would be like one who, charged to analyze the structural mechanics of a building, would ignore everything in the house but heirlooms brought over on the *Mayflower*. To learn the rules by which a thing works, it is necessary to study the thing as it works before one's eyes. The Maya elements in the contemporary culture of Yucatan are now thoroughly integrated with elements of European or modern American origin. The life in the villages is tied up with institutions that have their roots in the capital city, and with an economic system that includes the whole world.

The other assumption is to the effect that a description of contemporary Yucatan can be made more than a mere depiction of a static condition, because

the area, geographically homogeneous and racially simple, contains within it communities ranging in complexity from the family or tribal group of primitive Indians to Merida, the large urban capital. If comparative studies are made of this series of communities, we shall acquire most valuable information upon a process of social evolution typical of large parts of Latin America and, indeed, in its trend toward urbanization, characteristic of the whole modern world.

In accordance with these principles, Dr. Redfield organized a survey of Yucatan which included research upon groups at various stages of advancement. At the foot of the ladder were the Maya of the remote villages in the eastern forests, people who, since the general revolt against the whites in the 1840's, have never been reconquered and have held themselves aloof from Mexican influences. This work was carried on through several seasons by A. Villa R. The next upward stage was represented by Chan Kom, a small pure-Maya settlement which was just beginning to feel the impact of the outside world. Still farther within the zone of modern influences was Dzitas, a small town on the railroad, preponderantly Maya but with a sprinkling of Latins. There Dr. Redfield lived with his family for several months. Completing the ascent to urbanization was Merida, the capital, where A. T. Hansen spent two years in studies of all classes of society. A report upon Chan Kom by Dr. Redfield and Sr. Villa has been published and manuscripts upon the other communities are in preparation, together with a concluding work by Dr. Redfield, summarizing the results of the whole investigation.

While the survey of Yucatan was still in progress a similar undertaking was begun in the highlands of Guatemala, a region largely populated by

Maya-speaking Indians, but one in which environment, pre-Columbian events, and post-Conquest history have combined to produce modern conditions very different from those obtaining in the Peninsula. Sol Tax, who joined the Division in 1934, has devoted himself entirely to the Indians of this area, and his work has been supplemented by investigations by Dr. Redfield of the life of the lower-class mixed-bloods or Ladinos, who form a connecting link, culturally, between the Maya and the ruling whites.

Dr. Tax, during the past five years, has made his headquarters in the central western highlands, studying intensively Chichicastenango in the Quiche country and the Cakchiquel town of Panajachel on Lake Atitlan. He has also done comparative work at the several other communities of the lake district.

In the winter of 1938-1939 Dr. and Mrs. Tax re-established themselves at Chichicastenango. Dr. Tax revised previously collected materials on this town, resumed preparation of a monograph on Panajachel, and supervised the activities at San Pedro, on Lake Atitlan, of Juan Rosales, an educated Panajachel Indian who has for several years been of great assistance in gathering linguistic texts for Dr. Andrade and ethnological data for Dr. Tax. Dr. Redfield devoted part of his time to further study of the Ladino culture of the lake area and part to work on the manuscript embracing the final results of the Yucatan project. Sr. Villa spent the year in Mexico and the United States, studying at the University of Chicago and completing his report on the primitive Maya communities of eastern Yucatan. At the request of the Mexican Government Sr. Villa has been detailed to assist the Mexican Department of Indian Affairs in a survey of the Totonac peoples of Veracruz.

With reference to the study of the contemporary Maya society of the

Guatemala highlands, the present plan is for the preparation of from three to five publications: (1) a general monograph on Panajachel (Tax); (2) a special monograph on the economic life of Panajachel, to be prepared so as to bring it into comparable relation with similar studies of modern communities in other parts of the world (Tax); (3) a descriptive monograph, to be written in Spanish for the value it is likely to have for Guatemalan and Mexican students, on San Pedro Atitlan (Tax and Rosales); possibly (4) a publication of such aspects of the life of Chichicastenango as are well represented in Tax's materials (Tax); and possibly (5) a study of the Ladino-Indian community of Agua Escondida (Redfield).

The study of these present-day Guatemalan societies is in need of cooperative planning. In recent years ethnological research has been carried on in the highlands not only by this group of students but also by others not connected with Carnegie Institution. It is desirable that the knowledge obtained and largely unpublished by all recent workers in the field be brought together and exchanged. This can best be done in an extended conference. Such a conference should go far to clarify problems in the field by making more apparent than is now the case which elements are widespread in the area and which are local, and by emphasizing the more important lines of inquiry. Extensive survey should be combined with intensive research on selected communities. But until it is known what problems are important, it will not be possible to plan the survey wisely nor will it be possible to know which communities should be chosen for intensive study.

The experience to date of Dr. Redfield and Dr. Tax suggests that further prosecution of certain lines of research would go far toward providing better under-

standing of social conditions in the Guatemala highlands:

1. *The existence and approximate limits of subcultural areas in the midwest highlands.* We do not know if the similarities and differences of the cultures of the *municipios* are such that the latter can be grouped into units of contiguous jurisdictions. Some of the facts which must be taken into account in approaching an answer to this question follow: (a) In some *municipios* the Indians live in towns and work the surrounding fields by the day; in others, the Indians have their homes and their farms in the open country and come to town only on special occasions; in still others—of either type—there are settlements subsidiary to the town; and other *municipios* (in fact most) are combinations of the other types. In the area so far visited and studied, there are three islands of the first kind of *municipio* in a sea of the second kind. One island consists of three towns south of Quetzaltenango; another of the ten towns of Lake Atitlan; the third of at least some of the towns of the department of Sacatepequez, just west of Guatemala City. In at least the first two cases the condition of the Indians living in towns is probably explicable on the basis of peculiar topography; the third case has not been studied. (b) *Municipios* tend strongly to be individually specialized with regard to the ways of making a living. Some of these distinctions are closely related to geographic differences, as that between coast lands and highlands, but others are not. We shall probably be able some day to mark off distinctive trade regions. (c) Each *municipio* differs from many or all others in dialect and general culture. These are not dissimilarities merely in costume and in saints' days, but also in many details of social customs, in kinship classification, etiquette, and ideals of social behavior. (d) Some of the differences in Indian culture are probably attributable to "ladino-ization." It may roughly be said that there are areas where the Indian culture is "purer" than in others. The differences among the *municipios* studied appear to be in details, apparently in all phases of the culture. But in some details the variations seem important, as for example that between communal house building and individual house building (San Pedro vs. Panajachel and Chichicastenango); and in some phases of the

culture the peculiarities seem greater than in other phases (for example, there seems to be more to sorcery and shamanism in general in Chichicastenango than in either San Pedro or Panajachel). Our problem is to plot the differences, then with samples extend our studies to other towns (like border towns) of the region to see what kind of areal consistency they have; it is not unlikely that we shall find that subculture areas will coincide with language areas, in which case they become of ethnological (historical) importance.

2. *The fundamental forms of social and politico-religious organization.* In each of the *municipios* that we know there is an institutional configuration consisting of (a) informal kin and local groups and (b) a structure consisting of separable but dovetailing political and religious organizations. In what is probably the basic theory of Indian social organization, the two elements are inextricably bound together in one system which has for its functions, first, the control of individual conduct and, second, the performance of services deemed necessary to the material and spiritual well-being of the community. In this frame of reference, the major problem is to determine by comparative (and, where possible, historical) methods what the basic system is and how and why its manifestations vary from *municipio* to *municipio*.

3. *Economic organization of the region.* One problem here is the distinction between the geographic and the more purely traditional factors in bringing about the economic specialization of Indian communities. Aside from the effects of altitude, natural resources, and quantity and quality of land, there are certain differences of economic organization which are not so directly attributable to the habitat. Contiguous *municipios* with closely similar resources vary sharply as to the extent to which these resources are exploited.

The full explanation of *municipio* specialization must take into account that, among other factors, (a) the economic specialization of the *municipio* is an aspect of its general cultural individuality; (b) the *municipios* are specialized with reference to crops, industries, trades, merchandizing, and labor, each of which requires separate treatment; (c) in addition to special circumstances of resources and geographic position that must be taken into consideration in individual cases of spe-

cialization, there are some general factors encouraging or discouraging the adoption of new means of making a living. Among the discouraging factors is the endogamous tendency of the municipios, which, since arts and techniques are largely transmitted from parents to children, tends to perpetuate specialties. Another is the competition that the innovations meet in existing means that are supported by tradition. A third is the shortage of capital that can be risked in innovations in an economy so close to the subsistence level. On the other hand, among the factors encouraging change (and economic homogeneity) may be mentioned the continuing contacts with other municipios having more profitable specialties, especially since such contacts exist in a free capitalism and together with the desire of individuals to improve their positions.

4. *Problems of ethnic relations between Indian and Indian, and Indian and Ladino.* Consideration given by this group of workers to the latter half of this problem suggests the following two broad generalizations as a basis for the study: (a) The Ladinos and Indians of the region have at one and the same time characteristics of distinct cultural groups in process of assimilation, and characteristics of social classes. An investigation of the situation in this regard in other selected communities in Guatemala should provide us with a series of instances ranged in an order of difference as to the two characters: separate cultural groups or well-defined status groups in a society with a single culture. Comparison of such instances would give knowledge as to how this transition, which we know to have occurred a great number of times in the recent history of our Western world alone, may come about. (b) The relations between Ladinos and Indians in this area are substantially without conflict. Nor is there any apparent disposition for the Indians to be held in a castelike status of lasting inferiority. The region is occupied by two ethnic groups, of which one maintains a culture much like that of the original conquerors, its members tending to identify themselves with these conquerors, while the other group are known as natives and so know themselves. Yet they live amicably in a common territory. Why do they live together so amicably, why is ethnic membership of so little social consequence, why are there no taboos or rituals or

myths to maintain the superior status of the one and the inferior status of the other?

5. *Problems of culture type and culture change.* The general questions may be asked: To what extent do elements of culture and society found in Guatemala have a necessary or natural connection with one another? What are the factors which have favored the spread of certain elements of culture and society in Guatemala and have limited the spread of others? Suppose we are able to say: The highland cultures are highly commercial and individualistic; exterior, impersonal institutions are important in social control; there is abundant practical magic; the treatment of the supernatural is magical and practical, and does not characteristically involve strong personal experiences with the supernatural. Then it should be possible to make it clear which of the institutions and elements of culture are consistent with, perhaps functionally related to, others. A detailed comparison of certain Indian cultures, selected to represent differing degrees of intimate contact with the Ladinos, would probably give us some understanding of characteristic ways in which older culture elements (in some cases aboriginal elements) in this area changed their nature under modifying influences. For example, in Panajachel the group of beliefs about the beings inside the hill exists in a form which apparently identifies the hill with hell and the lord of the hill with the devil. In San Pedro the hill beliefs exist without this evidence of fusion with European notions. Certain cosmogonic beliefs probably exist in San Pedro in a more nearly aboriginal condition than in Panajachel. The point to be stressed here is not a hope that we shall find any village in which pre-Conquest culture is approximated, but rather that by comparing the varying forms of what must be basically the same idea or institution we shall learn something of how culture changes under certain sorts of influences. It may not be impossible to learn, by such comparisons, something about the progressive disappearance of collective community ownership of agricultural land which has probably occurred at least in the lake region.

The comparison of municipios already made, slight as it is, raises the question: What truth really underlies the statement so

often made that the Guatemalan highlands constitute a region of great cultural diversity? It now appears that the local differences are accompanied by widespread and very important uniformities. Apparently the local variations in culture are of a sort that strike the observer in the first stages of his understanding of the highlands, while the uniformities appear greater after a more intimate understanding is reached. The municipios differ in features that are conspicuous: costume, dialect, traditional dances, local products, special forms of ritual. These contrasts make the highlands appear a crazy quilt of cultures. The visitor is struck by the way in which, within a few miles, he may pass from Indians who wear one kind of costume, make houses of one form, and speak a certain language, to Indians who differ in all these very apparent respects. But it now appears to us that these obvious diversities are relatively exterior, and that with respect to characters which make for the maintenance of a common life together, the Indians, and the rural Ladinos too, may be much more alike than they are different. It might be enlightening to study some of these societies in terms of those institutions which are recognized by Indians of all communities and by Ladinos too, and which make it possible to establish relationships across local communities: buyer and seller; *recomendado*; *posada*; complaint before the *intendente*; godparent-*compadre*, etc. Other problems under this general head are the following: How is it that the sharing of so many common understandings between Indian and Ladino does not necessarily require that they come to agree with reference to understanding of the supernatural and as

to the interpretation of Nature? To what extent is the overt rational life of the Indian an expression of personal religious sentiment and to what extent is this ritual magic impersonally executed by professionals? This leads to the question: How is the religion of this people adjusted to their highly practical and highly commercial manner of life?

During 1939-1940 Dr. Redfield and his associates will devote themselves to analysis of materials, writing, and conference, in an attempt to organize effort with reference to problems such as the above.

Conforming to the program of Dr. Andrade's linguistic survey of Guatemala, a study of the Quekchi language of Alta Verapaz was the object of the field work done during the first quarter of 1939. In most respects, Quekchi was found to be merely one of the variants of the main group of Maya languages spoken on the highlands of Guatemala, differing hardly more from the contiguous members of this group than they differ from one another. Since Quekchi differs considerably from Mopan and Chol, it seems that the rather gradual divergence of the language of the highlands from Mam as a center comes to an abrupt end on the northeast as we pass from Quekchi to the languages north of Alta Verapaz. From the inquiries made in this field trip, it seems rather definite that Chol is no longer spoken in Alta Verapaz.

UNITED STATES HISTORY

L. F. Stock's work of editing volume V of the *Proceedings and debates of the British Parliaments respecting North America* was interrupted by his visit to England, where he spent the spring and summer of 1938 on a profitable search for further materials for the succeeding volumes of this series. Particular attention was there given to the debates in the Thirteenth Parliament of Great Britain,

1768-1774, which were singularly little reported for these years of exceptional importance to American history. Henry Cavendish, a member, took copious and careful notes throughout all the six sessions of this Parliament. In 1839, John Wright, who had been the editor of Cobbett's *Parliamentary history*, discovered Cavendish's reports among the Egerton Manuscripts in the British Mu-

seum, and published the notes on the debates of 1774 concerning the Quebec Act of that year. Wright proposed to print the whole of Cavendish's record. His advertisement announced that the work would consist of four or five octavo volumes and would be published in parts, four of which would constitute a volume. Volume I was completed in 1841. Parts five, six, and seven made up a second volume. This is all that was ever published; the work ends in the middle of a speech on March 27, 1771. Wright died in 1844.

The collation of Wright's volumes with the original manuscripts, earlier made by the Division, showed that the printed version was often summarized and paraphrased. These differences were corrected. Dr. Stock made an effort to fill the gap between March 27, 1771 (when Wright's volume ends) and the debates printed in the volume for 1774 on the Quebec Act. Some success was achieved.

Unfortunately most of Cavendish's notes are in shorthand and the problem of completing the transliteration is a difficult one.

In addition to the Cavendish notes, much other material was found for text and purposes of annotation.

Since his return Dr. Stock has continued his work on volume V of the series. The Spanish War, begun in 1739 (when volume IV ended) and continuing in other phases until the treaty of Aix-la-Chapelle, 1748, occupied the chief attention of Parliament during these years. North America figured extensively in the proceedings and debates.

Dr. Stock represented the Institution at the Eighth International Congress of Historical Sciences, held at Zürich, August 28—September 3, 1938. In December he described his work for the Institution before the District of Columbia Chapter of the Society of the Sons of the Colonial Wars.

HISTORY OF SCIENCE

In his work of compiling the *Introduction to the history of science* Dr. Sarton has completed during the past year the Latin and Greek notes of volume III, dealing with science and learning during the fourteenth century, except a few which had to be postponed for various reasons. The end of the work is now in sight. If all goes well, the analytical stage will be over by the end of 1939; then the years 1940 and 1941 would be devoted respectively to the synthesis and to the printing and preparation of various tables and indices.

During the course of the past year four numbers of *Isis* were published (78 to 81), forming volume 29 and two-thirds of volume 30, plus volume 5 of *Osiris*, devoted to the longer memoirs: a total of 1628 pages, illustrated with 15 plates, 93 figures, containing 43 memoirs, 32 shorter notes, 107 reviews,

and 2570 bibliographic items. It is worth while noting that every memoir published in *Osiris* (eleven this year) is the subject of a separate analytical card issued by the Library of Congress. The same could not be done for *Isis*, the contents of which are far too abundant.

In the editing of *Isis* and *Osiris*, proofreading, and correspondence *ad hoc* Dr. Sarton was helped by Dr. Pogo. Since the latter's return from Washington to Cambridge at the end of November 1938, his cooperation has been much increased, not only because proximity made it easier and obviated the need of correspondence, but also because while Dr. Pogo was in Washington much of his time was devoted to Maya astronomical computations and to correction of the proofs of Dr. Morley's *Inscriptions of Peten*.

Dr. Sarton gave a course of about

thirty-three lectures on the history of modern science (eighteenth century and after) at Harvard University and also at Radcliffe College. He conducted a seminary on the study of the history of science attended by Harvard and Radcliffe graduates (twenty-four meetings). He delivered five lectures: (1) October 25, "Transcendental history," Winthrop Club, Emerson Hall; (2) November 9, "Function of academies past and present," American Academy of Arts and Sciences, Boston; (3) November 17, "Science during the French Revolution," Carnegie Institution, Washington, D. C.; (4) December 29, "Comenius and Bayle," History of Science Society, at annual

meeting of the American Historical Association, Chicago; (5) December 30, "Oriental science," joint meeting of the History of Science Society and the American Oriental Society.

The staff of this section was modified in various ways. Dr. Mary Catherine Welborn resigned in October. Dr. Pogo came back from Washington at the end of November. Mr. I. B. Cohen was continued as a fellow and devoted much of his time to routine work of various kinds (arrangement of the library and portraits) and to the study of the history of the early determination of the speed of light and of the theories of light since Newton.

PUBLICATIONS

The publications of the Division in the past decade have undergone extensive change both in scope and in format. The early thirties were devoted to two phases of publication: Middle American archaeology and United States history. The series in the latter field, however—guides to materials in European archives for American history, European treaties and proceedings of British Parliaments bearing on the history of the United States, letters of members of the Continental Congress and correspondence of Andrew Jackson, documents relating to New Mexico, and to American slavery and the slave trade, and an atlas of the historical geography of the United States—were gradually brought to a close. The final volumes of all these groups, with the exception of the parliamentary debates, have been published.

In 1897 began the compilation which later became the *List of doctoral dissertations in history in progress at American universities*. Since 1918 the list has been a separate pamphlet issued annually by the Division and since 1935 compiled by Mrs. Harrison. The issues of 1936, 1937, and 1938 were greatly en-

larged, the format revised to provide for serialization and cross reference of entries, and the distribution widened. Lately it has been felt that a project of this nature no longer had place in the present program of the Division's activities, and this year an arrangement was made whereby the American Historical Association took over the compilation and publication of this list.

The first two volumes of Dr. Sarton's *Introduction to the history of science* appeared in 1927 and 1931, respectively, and much of the material for volume III is prepared. Shorter studies in this subject are published in *Isis* and *Osiris*, and elsewhere.

With the reorganization of the Division in 1929 and the subsequent shift in emphasis to investigations, both archaeological and historical, in the field of Middle American research, the increase in the preparation of reports covering this aspect of the Division's work led to the assignment in 1934 of Margaret W. Harrison to the editorial duties connected with both the concluding volumes in the United States history series and the reports in archaeology.

Besides two works published in the early twenties on Copan and Tulum, the Division has produced since 1930 nineteen monographs on the Institution's work at Chan Kom, Chichen Itza, and Coba, in Peten, and at Quirigua, San José (British Honduras), Uaxactun, and Zacualpa; zoological and botanical studies of the Maya area; medical and biological surveys of Yucatan and Guatemala; two editions of documents in the Maya archives; and five volumes of Contributions to American Anthropology and History (formerly entitled Contributions to American Archaeology). In press at this time is an extensive report on the archaeology and pottery of the La Plata district by E. H. Morris. Studies published during the past year are listed in the bibliography.

Beginning early in 1939, experiments were made in the direction of a less elaborate but equally effective format for

the Division's publications. Instead of the large type and wide type page, a small, easily read, two-column page has been substituted with much success. Line cuts have been reduced proportionately but without loss of legibility. Photographic illustrations are much decreased in size, but to ensure no sacrifice of detail they have been reproduced by the full-tone process, whereby remarkable clarity is maintained and at the same time minute objects may be brought up with a magnifying glass. This arrangement provides for many more illustrations to a page and therefore to any given book.

Mrs. Harrison has under preparation at the present time a list of selected references on the Maya area. These will include important periodical articles as well as the foremost books on the subject. This list will bring up to date the leaflet issued in 1935.

**REPORTS ON INVESTIGATIONS BY RESEARCH
ASSOCIATES AND ON SPECIAL
COOPERATIVE STUDIES**

ANTHROPOLOGY

SOPHIE D. ABERLE, United Pueblos Agency, Albuquerque, New Mexico. *Anthropological and economic studies of Pueblo Indians*. (For previous reports see Year Books Nos. 34, 36, 37.)

These studies, begun by Dr. Aberle a few years ago, were made possible by means of a grant from the Carnegie Corporation of New York in cooperation with the research program of the Carnegie Institution of Washington.

During the past year a paper, "Vital statistics of the Pueblo Indians," has been published which includes an analysis of the modern birth, death, and population figures for the entire Pueblo population in New Mexico. A paper

has been prepared on "Vital history of San Juan Pueblo," and is to be published soon, this study including an analysis of the population, births, and deaths of the San Juan Pueblo Indian village, as compared with neighboring Spanish-American villages, for a period of over 200 years. The data for this study were obtained from the original records of births, deaths, and marriages kept by the parish priests.

ARCHAEOLOGY

MARION E. BLAKE, Rome, Italy. *Preparation and completion for publication of the first part of a monograph on Roman building construction, based upon materials accumulated by the late Dr. Esther B. Van Deman.*

This report covers the ten months from September 1, 1938 to July 1, 1939. Some time was of necessity spent in a preliminary mastery of the field. The difficulties encountered in verifying the generalities repeated in most of the books dealing with parts of the subject reveal how great is the need for an authoritative work on Roman construction.

Much time has been devoted to bringing Dr. Van Deman's notes up to date. They stop abruptly in 1922, when she turned her attention to the aqueducts. There has been a tremendous amount of archaeological activity in Rome in the seventeen years between 1922 and 1939. The remains of no less than ten temples have been or are being more or less opened up for study, to give a single illustration. So far as these results have been published, Dr. Blake's knowledge of them is now fairly complete. Most of the field work remains to be done.

The monograph is about half written in the first rough draft. For the time being, Dr. Blake is treating each chapter as though it were a separate monograph so that no matter what the future may hold, what has been completed can be published with little difficulty. To be more specific as to the part covered,

the section on materials (chaps. III and IV in Dr. Van Deman's outline) is practically finished with the exception of the paragraphs on wood and marble. The part devoted to mortar, forerunners of concrete, and concrete (chaps. V, XII, XIII, XIV) is about half done; that is, it is complete to the halfway point of the portion dealing with concrete. Of the facings, squared-stone masonry (chaps. IX, X) is about half done; rubble and reticulate work are untouched; a preliminary study of sun-dried bricks (chap. VII) and of brick stamps (chap. VIII) has already been completed; arches and vaults in square stone construction (chap. XI) await attention. Introductory and concluding chapters always remain for the end.

The prospects are that the monograph will be near completion by September 1, 1940, although there may be cause for delay in the necessity for careful review of all recent studies on Roman brickwork. There is also question whether it may not be desirable to include in the completed monograph a section devoted to Roman pavements as an integral and rather neglected part of the study of Roman construction.

ALFONSO CASO, Mexico City, Mexico. *Archaeological and historical studies in Oaxaca, Mexico.* (For previous reports see Year Books Nos. 35, 36.)

During the winter of 1939 Dr. Alfonso Caso, Director of the Instituto Nacional de Antropología e Historia of the Government of Mexico, continued his explorations and excavations in Oaxaca. The work was in part financed by a

grant from Carnegie Corporation of New York, administered by Carnegie Institution of Washington.

At Monte Negro de Tilantongo in the Mixtec area Dr. Caso investigated the ruins of Temple T S. The roof of this

building proved to have been supported by six columns. Toward the rear was found a large pottery incense burner in the form of a human head of the early, widespread "Olmeca" type. Beneath and beside the temple were tombs yielding abundant pottery and jade ornaments.

In superficial earth, covering a second tumulus called the Mound of the Mask, there came to light an alabaster mask and portions of its turquoise mosaic incrustation. This, being in the style of Teotihuacan, was evidently an importation. With it were several small carvings in green stone referable to the third period of Monte Alban.

Exploration of other buildings, courtyards, and tombs provided further architectural data and information regarding the minor arts.

The similarity of the pottery of Monte Negro to that of the first period of Monte Alban leads Dr. Caso to believe that these two cultures were contemporaneous. He also considers, because of the "Olmec" features jointly possessed by Monte Negro-Monte Alban I and the Archaic cultures of the Valley of Mexico, that both groups should be assigned to the same chronological horizon. If this be so, the relatively more advanced architecture and jade work of Monte Negro-Monte Alban I would suggest that the Valley of Mexico Archaic was a somewhat retarded development peripheral to an important early center of cultural dispersion located in Guerrero, Oaxaca, Veracruz, or Chiapas.

The discovery of the Teotihuacan-style mask in a post-Monte Negro stratum at that site in association with objects of the third Monte Alban period adds significantly to that knowledge of time and trade relations in prehistoric Mexico which is so necessary for ultimate historical reconstruction.

At the great site of Monte Alban, Dr. Caso carried forward his program of excavation and repair. Several mounds were investigated, and five tombs and

twenty-two lesser graves opened. At Mound IV were found fragments of a stone monument 5 meters in height, bearing large glyphs and numerals in the bar-and-dot system. Beneath the stela were buried a pottery vessel of Period II and jades. As Dr. Caso considers Monte Alban II to antedate the Maya Old Empire, he is led to believe that the stela cult and practice of making sub-stela offerings already existed at Monte Alban at a remote period.

In Edifice B of the complex known as the "Sistema del Vértice Geodésico" there was unearthed a remarkable ceremonial offering, a miniature clay temple, its pyramidal roof upheld by eight columns. On the floor of the temple, below an opening in the roof, was the figure of a macaw. According to an old legend, when the Zapotecs founded their first city in Teotitlan del Valle, they built a temple to the sun god Xaquija, who had descended from the sky in the form of a macaw. It is therefore probable that the present object is a representation of the temple of Xaquija, the opening in the roof permitting the bird to descend from the sky and enter his sanctuary. The red-on-orange pottery of which the specimen is made is characteristic of Period II.

Interesting architectural data were recovered from Mound M and the Temple of the Dancers. An offering pit on the north slope of Monte Alban contained pottery, jade figurines, shell, and a disk decorated with jade mosaic.

In the early part of the year, Sres. Valenzuela and Romero investigated a mound with its temples, a ball court, and two courtyards at Atzompa, a perhaps independent ceremonial center near Monte Alban, which, from pottery found there, may be assigned to the Monte Alban III period.

Architectural studies and repairs were carried out at Mitla.

Dr. Caso's detailed report is on file at the Division of Historical Research.

ASTRONOMY

BENJAMIN BOSS, HARRY RAYMOND, and ISABELLA LANGE, Dudley Observatory, Albany, New York. *Special studies based upon utilization and interpretation of materials in the General Catalogue of Stars.* (For previous report see Year Book No. 37.)

During the past year studies have been pursued bearing upon the question of solar motion, galactic rotation, and precession. It has become evident that the apparent direction of solar motion is dependent upon the character of the group of stars from whose proper motions it is determined. As the sun can only be moving in a particular direction, the anomaly indicates that stars of different classifications are subject to different group motions. There is also the question of the type of rotation in our galaxy. In order to test the effect of distance upon solar motion and galactic rotation, two groups of stars were selected ranging from type B8 to type Ma, the one limited to stars whose hypothetical parallaxes are less than 0.007 and the other to stars included between parallaxes 0.007 and 0.014. The apex of solar motion derived from the more remote group is at R.A. $276^{\circ}2$, Decl. $+46^{\circ}0$, and the apex from the nearer group is at R.A. $271^{\circ}2$, Decl. $+36^{\circ}2$. The solar velocity derived from the remote group is 14.1 km. per second, and that from the nearer group 16.0 km. per second, based upon the logarithmic mean of the hypothetical parallaxes. The surprisingly small value for solar velocity might be attributed to systematic errors of the hypothetical parallaxes, but an investigation was made of their accuracy through a comparison of trigonometric, Mount Wilson spectroscopic, and hypothetical parallaxes, and the results indi-

cated that the hypothetical parallaxes were systematically smooth and that their errors are of the same order as those of the spectroscopic parallaxes. While it may be that some of the observed differences in solar motion derived from the two groups are due to distance effects, the fact that selection by hypothetical parallaxes also involves selection by small proper motion, in part, indicates that the size of the proper motion is also a factor, possibly the chief factor. The cause of the small value for solar velocity is under investigation.

Solutions based upon other classifications such as giant series stars and stars of different luminosities and of different spectral types are under way with a view to clarification of the anomalies encountered in the determination of solar motion.

The method of determining hypothetical stellar luminosities reported in Year Book No. 37 (1937-1938) has been employed in investigating the luminosities of the stars in the Taurus, Pleiades, and Praesepe clusters. The range in luminosities in each cluster can most reasonably be explained on the basis of obscuration, and a rough value of the obscuration factor was derived for the three clusters. It was shown that the group velocities of the Taurus and Praesepe clusters are nearly the same, and that the direction of the motion is nearly parallel.

S. A. MITCHELL, University of Virginia, University, Virginia. *Astronomical studies at the Leander McCormick Observatory.*

In 1933 the Carnegie Corporation of New York made funds available through the Carnegie Institution of Washington to cover cost of appropriate mounting at the Leander McCormick Observatory of a 10-inch Cooke triplet camera loaned to this observatory by the Mount Wilson Observatory of the Carnegie Institution. A small additional fund has recently been made available by the Corporation for support of studies undertaken with this instrument and other telescopic equipment of the Leander McCormick Observatory.

With the addition of an objective prism, the 10-inch Cooke is used chiefly to determine photovisual magnitudes and also to secure the spectra of faint stars. Photovisual and not photographic magnitudes are derived so that these magnitudes may be utilized for work with the 26-inch visual refractor. With photographs from the 10-inch and 26-inch telescopes and by visual observations with the large telescope, the visual magnitudes of sequences of comparison stars for 50 long-period variables have recently been determined. For 2 of the variables, namely, for Nova Herculis and Nova Lacertae, the results have been published. The whole material will appear in print as a publication of the Leander McCormick Observatory.

In 1937, there appeared volume VII of the *Publications* of this Observatory giving a discussion of the proper motions of 18,000 stars, derived from photographs of 341 regions originally photographed by the 26-inch refractor for trigonometric parallaxes. The scientific results brought information of such value that it was decided to photograph additional regions in the sky where parallax plates with a minimum time interval of 12 years are available. The process of taking and measuring the plates is now in progress, with 450 regions on the program. There

will be 12,000 additional stars to discuss along with the earlier 18,000 stars.

With the 10-inch Cooke and objective prism it is possible to secure spectra of faint stars included in this proper motion work down to about the 12th photographic magnitude. Moreover, with the 10-inch the whole sky is being photographed with zone plates north of 15° south declination in order to derive photovisual magnitudes that are needed in several of the large programs that are in process at this Observatory. One of these problems is the determination of the proper motions of more than 200 Cepheids, which is being done in cooperation with Mount Wilson Observatory, duplicating the work of van Maanen. With the combination of proper motions of Mount Wilson and McCormick, and with the radial velocities already determined by Joy, the parallaxes of the Cepheids will be derived and hence it will be feasible to derive distances in the stellar universe with greater precision than heretofore, by determining with greater accuracy the zero point and scale of the period-luminosity law.

It is anticipated that with cooperation of the McDonald Observatory photographs will soon be made of the spectra of stars of about the 10th magnitude which have been measured at the Leander McCormick Observatory for proper motion. The radial velocities of these stars together with the proper motions will give the motion of the sun with respect to faint stars. The position of the solar apex and the velocity of the sun's motion have very different values when referred to the bright stars and to fainter stars of different magnitudes and spectral types. It is expected that the radial velocities of faint stars will give valuable information for the interpretation of these differences in the solar motion.

BIOLOGY

W. E. CASTLE, University of California, Berkeley, California. *Experimental studies of heredity in small mammals.* (For previous reports see Year Books Nos. 3-37.)

The mouse investigations described in last year's report are nearing completion and will shortly be ready for final publication. They show that the gene mutations leaden and pink-eye₂ reduce adult body size, when homozygous; and that yellow, when heterozygous, increases body size, though when homozygous it is lethal. It had previously been found that the brown mutation (substitution of chocolate brown pigmentation for black throughout the body) increases body size in mice by 2 to 5 per cent. A similar brown mutation in rats and in rabbits, it is now being found, also increases body size in those species, and the writer has been told by an intelligent breeder of dogs that the same thing appears to be true in dogs. For some physiological reason as yet undiscovered, it would seem to be true in mammals generally that the brown mutation is an accelerator of growth.

Data have now been accumulated on the influence on growth of several mutations affecting the color or morphology of the mouse. Some of these accelerate growth, others retard it. Some are dominant (as yellow), but most are recessive. But all of them are *either* dominant or recessive. In the classic theory of color inheritance, it is assumed that size genes are devoid of dominance, and that this is why size crosses regularly produce intermediates. The evidence which is being produced in this series of experiments

suggests a different interpretation, that the intermediate character of F_1 is due to the combined action of some genes which tend to increase size and that of others which tend to reduce it. Most mutant genes tend to reduce size and are recessive. So a cross usually results in rendering them inactive and yields a heterosis effect, a manifestation of cross-bred vigor, in which offspring are superior in size to either parent.

The linkage studies of the rat are progressing favorably. One new linkage has been established between the new lethal and recessive gene, anemia, and curly coat. The crossover percentage is about 5. The same chromosome which carries curly and anemia also carries the mutant gene brown. A cross is now being made to ascertain the order and map distances of the three genes. A new mutant rat gene, hereditary jaundice, is being investigated as to its linkage relations. A foundation stock was kindly supplied by Professor MacArthur of the University of Toronto, in whose laboratory it was discovered.

The rabbit investigations are progressing satisfactorily but no new conclusions have been reached except as to the accelerating influence of brown pigmentation on growth, as already indicated. More data are desirable before this tentative conclusion can be regarded as fully established.

PAUL S. CONGER, Washington, District of Columbia. *Investigations and preparation for publication of results of studies on Diatomaceae.* (For previous reports see Year Books Nos. 18-37.)

During the past year ten weeks were spent at the Tortugas Laboratory of the Carnegie Institution, where four major lines of work were pursued, as follows: (a) description and drawings in detail of the morphology and reproduction of a new species of *Amphora*, which illustrates particularly well the process of vegetative reproduction; (b) observations and experiments on movement in certain species of diatoms, which led to a new idea of the general principle of movement in diatoms; (c) a study of the silica relationships between the diatoms and sea water in this region very low in dissolved silica or siliceous sediments; (d) description of the living aspect (heretofore unrecognized) of various diatoms. Studies were continued on the general flora of the region, and on the structure of certain forms.

In a month during the latter part of August and early September work was carried on at the Trout Lake Biological Laboratory of the University of Wisconsin in cooperation with the University and with the State Geological and Natural History Survey. Further collections of sediments and plankton were made from 45 lakes in the surrounding region, and from a number of bogs.

Analyses were made during the year of sediments from 70 northern Wisconsin lakes, relative to the value of their diatomaceous content. On the basis of these analyses, and of the finding of some very concentrated deposits, a paper was prepared and presented before the Limnological Society of America at the Richmond meeting of the American Association for the Advancement of Science, entitled "Diatomaceous peat deposits in the glaciated area, and the conditions of their formation." An illustrated article on the general subject "Diatomaceous

peat deposits, and the conditions of their formation" was prepared for publication in a forthcoming issue of the *Scientific Monthly*. The work described represents two essentially new findings: (a) the discovery of extensive diatomaceous peats in Wisconsin and other glaciated lake states in various stages of active formation, and (b) determination of the factors involved in, and elucidation of the general principles of formation of, highly pure diatomaceous deposits of industrial quality.

A paper was published in the *American Journal of Science* entitled "The contribution of diatoms to the sediments of Crystal Lake, Vilas County, Wisconsin." This was a companion paper to one by Dr. W. H. Twenhofel and Mr. W. A. Broughton of the University of Wisconsin on a study of the mechanical analyses of the Crystal Lake sediments, and was based on 31 samples collected by these men in eight cores from the lake bottom. Since Crystal Lake is a small and exceptionally clear and soft-water lake, the study of the diatoms and ecological factors of these sediments was of more than usual interest. About 80 species were listed, and in some layers of the deposit diatom concentration was very high, as much as 50 per cent or more.

Thirty-five plankton and bottom samples were examined for Dr. J. W. Bailey of the University of Richmond in connection with pollution studies of the York River.

The report of diatomaceous deposits in northern lakes brought a greatly increased correspondence, and a considerable number of samples and requests for information, putting an extra heavy burden on the routine work of the laboratory. To relieve this, temporary help

was obtained for a period of two months in March and April.

A talk on diatoms was given before the Botany Seminar group of the George Washington University, and another to the Seminar group at the Trout Lake Biological Laboratory.

More important lots of material received and examined during the year were several hundred samples each of the Captain Robert Bartlett Greenland Expedition, and of the latest Byrd Antarctic Expedition.

A detailed report was prepared on

sixteen samples of fresh-water diatomaceous earth and one marine earth from New Zealand for the Department of Mineral Resources of the Dominion Laboratory of the Government of New Zealand. This is to be included soon in a more general published report by the New Zealand Government.

A student from the Department of Zoology of the University of Maryland studied diatoms in our laboratory one day a week during the course of the school year, and cooperated to some extent in the work of the laboratory.

LEE R. DICE, University of Michigan, Ann Arbor, Michigan. *Studies of the ecology and genetics of North American mammals.* (For previous reports see Year Books Nos. 31-37.)

An investigation of the proportional occurrence of the buff and gray color phases of *Peromyscus maniculatus blandus* on soils of buff and of gray color in the Tularosa Basin of southern New Mexico was conducted by Dr. W. Frank Blair during the fall of 1938. On an area of dark red soil most of the mice trapped were of the buff color phase, and this was true also of the mice trapped on near-by gray soil. On an area of pinkish gray soil about 10 miles away, however, the majority of the mice were of the gray phase. A total of 653 live *Peromyscus* were shipped alive to the Laboratory of Vertebrate Genetics of the University of Michigan. Tests are being made to determine whether the buff animals taken in the field are homozygous or heterozygous for recessive gray. In addition to the two color phases, there is also much variation in depth of pelage color among the field-caught mice. All combinations of shade and hue seem to occur, ranging from pale buff and pale gray to moderately dark buff and moderately dark gray. The mode of inheritance of the pale color is now being investigated and an attempt is being made to determine

the degree of correlation between the occurrence of particular shades and hues of pelage color and the soil color of the trapping stations.

An estimate of the number of deer mice in the Black Hills of South Dakota and Wyoming, from trapping records secured on the expedition of 1935, indicates that in late summer of that year the population consisted of between 1,000,000 and 5,000,000 individuals.

Most of the new breeding stocks of *Peromyscus* received by the Laboratory of Vertebrate Genetics during the year were secured by Dr. W. Frank Blair in southern New Mexico, where the races *blandus*, *eremicus*, *nasutus*, and *tornillo* were taken. Stocks of *bairdii*, *crinitus*, *gracilis*, *megacephalus*, *nebrascensis*, and *noveboracensis* from the states of Michigan, Oklahoma, and Utah were received from other sources. A total of 1930 laboratory-reared mice were prepared as specimens during the year for studies of variation. Studies of variability were completed for a number of stocks and the results were prepared for publication.

Studies of linkage relations of the

mutant characters of the deer mouse, *Peromyscus maniculatus*, have been continued by Elizabeth Barto. Data now

available indicate that there is no linkage between the characters albino and dilute, nor between hairless and ivory.

T. H. MORGAN, JACK SCHULTZ, C. B. BRIDGES, and VIOLA CURRY, California Institute of Technology, Pasadena, California. *Investigations on the constitution of the germinal material in relation to heredity.* (For previous reports see Year Books Nos. 15-37.)

Schultz has continued on leave of absence, holding an International Fellowship of the Rockefeller Foundation, and working in collaboration with Dr. Torbjörn Caspersson at the Chemical Laboratory of the Caroline Institute at Stockholm. Their joint work, of which the report follows, has been centered about the relation between the nucleic acids of the nucleus and those of the cytoplasm, as part of the general problem of the relation between the nucleic acids and the genes. In pursuit of part of this program they have attempted to gain some evidence of the rôle of the cytoplasmic nucleic acids and of their synthesis in relation to the nucleus. The attempt has also been made by further analysis of the variegation process in *Drosophila* to obtain a better understanding of the distinction between the heterochromatic (so-called inert) chromosome regions and the euchromatic regions, which contain the "active" genes. The combined results of the different types of experiment give evidence that the cytoplasmic nucleic acids are of importance in growth and division, and that their synthesis occurs at the nuclear membrane or possibly within the nucleus and is controlled at least in part by the heterochromatic chromosome regions. These are regarded as containing special types of genes concerned especially with nucleic acid synthesis.

The rôle of the cytoplasmic nucleic acids in the mitotic process has been very little discussed. The results of the present year show that rapidly dividing or growing cells contain in general high

concentrations of pentose nucleotides in the cytoplasm. The methods used have, in the main, been the optical methods developed by Caspersson for the study of the absorption spectra of cell details. The high absorption in the near ultraviolet, with a maximum at 2600 Å, characteristic of the cyclic nitrogenous bases in the nucleic acids facilitates the identification of these substances. For the further definition of these absorbing substances as nucleic acids, microincineration methods have been used to show the correlation between presence of ash in the tissues and high amounts of absorbing substances. Tests for the presence of pentose have also been made in some cases, in which therefore the three components of the nucleotides—the ash for the phosphorus of the phosphoric acids, and the pentose and the nitrogenous bases—have been shown to be present. Measurements were made of the absorption spectra of the different types of tissue, the plan having been adopted of comparing, in the same organ as far as possible, cells where growth and division are at a maximum and those in which the processes of division or growth are minimal. Thus, in the larval *Drosophila* the imaginal disc cells of the gut—embryonic cells in function—occur in small nests among the functional, non-dividing cells of the larval gut. While the absorption spectrum of the imaginal disc cells shows a sharp nucleic acid maximum, that of the larval cells is almost characteristically protein, with a low absorption and the hump at 2800 Å due to the cyclic amino acids. A similar

situation was found in the study of the *Allium* root tip, where a comparison could be made between the absorption spectra of the cells at the tip of the root where the divisions occur, and those at the base which are no longer dividing.

Complementary evidence comes from the study of the cells of eggs and embryos. Embryonic tissues have been the classic sources of pentose nucleic acids, and in the rye embryo Behrens has demonstrated their presence in the cytoplasm. Measurements of absorption spectra of such embryonic or egg cytoplasm (rye embryo, *Drosophila* egg) show the presence of a high concentration of nucleic acids. Evidence from still a different type of experiment is supplied by Caspersson's data on the absorption spectra of yeast cells from rapidly dividing cultures as compared with those in which division is at a minimum. Here again there is an increase in the nucleic acid content correlated with an increase in the division rate.

Thus the pentose nucleic acids of the cytoplasm do play a rôle of importance in growth and division, and the question of the relation of these pentose nucleic acids to the deoxy-ribose nucleic acids of the chromosomes is of especial interest. It is possible, as Brachet has suggested, that the pentose nucleic acids are in some way the precursors of the thymonucleic acids; there has, however, been no evidence that the pentose nucleic acids occur within the nucleus. Such evidence has now been obtained. The nucleoli of the *Drosophila* salivary gland and of the germinal vesicle of the sea urchin egg are both negative to the Feulgen reaction, hence do not contain thymonucleic acid. Measurement of the absorption spectra of such nucleoli shows the presence of the absorbing bases of the nucleic acids, making it probable that pentose nucleic acids occur in the nucleolus. This is of interest in connection with theories of the function of the nucleolus according

to which it serves to provide material for the growth of the chromosomes.

Evidence concerning the rôle of the nucleus in nucleic acid synthesis has also been obtained. Measurement of the absorption spectra of different points in the cytoplasm, close to and farther removed from the nuclear membrane, show that the maximum concentration of nucleic acids in cytoplasm is found around the nuclear membrane. These measurements have been made upon cells in which the amount of cytoplasmic nucleic acids is increasing, hence are consistent with the assumption that the synthesis of the cytoplasmic nucleotides occurs at the nuclear membrane or possibly within the nucleus.

It is noteworthy that changes in the pentose nucleic acid content both of the cytoplasm and of the nucleolus are effected by the heterochromatic chromosome regions in *Drosophila*. An extra Y-chromosome causes an increase in the concentration of the cytoplasmic nucleotides, as was reported last year. The nucleolar organizer is located in the heterochromatic regions of the X- and Y-chromosomes, and it has now been shown that the content of nucleic acids in the nucleolus is increased in a translocation involving the Y- and the second chromosomes. The heterochromatic regions have already been shown to have effects on the thymonucleic acid of the chromosomes, correlated with the genetical phenomenon of variegation. Thus the evidence is consistent that the heterochromatic regions contain genes influential in the nucleic acid metabolism of the cell.

The relation of the heterochromatic regions to the genetical phenomenon of variegation has been further studied in the salivary gland chromosomes of *Drosophila*. Parallel with this study, data have been obtained which provide a preliminary picture of the variability of the nucleic acid content of the different

bands, which should eventually be correlated with the genetic effects of the different regions. In the case of the variegated types it has been shown that correlated with the variegation there is an augmentation of the nucleic acid content of the bands in the genetically affected chromosome region. Evidence has now been obtained that this increase in nucleic acid content is, as was suggested, an intermediate stage in the transformation of the bands concerned into characteristically heterochromatic structures, which culminates in their loss as individual entities. The different stages of the change are well seen in an X-4 translocation (w^{vda}) involving an exchange of the left end of the X- and fourth chromosomes. At 25° C, when the variegation is slight, the bands in question (section 3F) show an augmentation of nucleic acid. At intermediate temperatures the augmentation is more pronounced, and at 16° the regular arrangement of the bands is replaced by an irregularity similar to that shown by the heterochromatic regions themselves. In most extreme cases the individual bands can no longer be made out. The parallel with the variegation process makes it probable that these changes are manifestations of changes in gene activity; for example, the greater the cytological similarity to heterochromatin, the more extreme the type of white allelomorph manifested in the variegation in flies raised under similar conditions. The variegation process, particularly when considered from the embryological point of view, seems to be concerned with the primary events in the differentiation of nuclei. A process of "heterochromatinization" of the different chromosome regions in the different tissues of the embryo, resulting in changes in the activity or in the loss of different genes, may be one of the mechanisms by which the differentiation of cytoplasm and nuclei is effected.

During the year 1938, Mrs. Viola

Curry has carried out some experiments which she and Dr. Bridges planned. Since Bridges' death (December 27, 1938) she has continued the work, and now submits the following report:

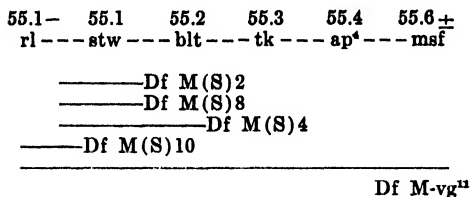
Study is being continued on two series of overlapping deficiencies in chromosome 2, one involving the straw region and the other the dumpy region, which were mentioned briefly by Bridges in Year Book No. 37 (1937-1938).

Five deficiencies, all Minutes, are involved in the first series: M-vg¹¹, M(S)2, M(S)4, M(S)8, and M(S)10. M-vg¹¹ bears no relation to the recessive vg¹¹ except that it was found to be a separable mutant, accounting for the Minute and the lethal effect, in the old vg¹¹ stock. At the time of the last report, M-vg¹¹ was known to be a deficiency for straw and to be lethal with M(S)2, M(S)4, and M(S)8, all of which likewise gave pseudodominance to straw in hybrids. (These last are Minutes obtained by Schultz from X-ray experiments.) Further studies have thrown some light on the genetic relations of these deficiencies, and have shown that M(S)10 is also involved.

M-vg¹¹ is the longest of the deficiencies. It includes, in serial order from left to right, the recessive mutant loci "rolled," "straw," "blot," "thick," "apterous," and "misformed," and is lethal with the deficiencies M(S)10, M(S)2, M(S)8, and M(S)4. Since rolled is mapped at 55.1 — and misformed is mapped at 55.6 ±, it covers a map distance of approximately 0.5 of a unit. Bridges reported after a preliminary examination that the salivaries showed an apparent loss of bands from 41A to the end of 42A. This was to have been verified when better material was obtained. On the map, M(2)p is placed between apterous and misformed, but the evidence here suggests that this seriation is incorrect and M(2)p lies to the right rather than to the left of misformed.

Concerning the salivaries of M(S)2, M(S)4, and M(S)8, Bridges reported: "None shows any detected effect in the salivary chromosomes, but since the region under suspicion is the chromocentric portion of 2R, the normal irregularities and adhesions there may be concealing the loss of bands." Further salivary studies are to be made, but the same difficulties probably will be encountered.

M(S)2 and M(S)8 are deficient only for the straw locus. M(S)4 is a deficiency for both straw and blot, located on the map as at 55.1 and 55.2. M(S)10 is a deficiency for rolled, but not for straw. All five of the Minutes are lethal alleles of each other. The relations of these five deficiencies, as determined genetically, may thus be represented as follows:



If successful salivary analyses can be made, this series of deficiencies offers excellent material for establishing correlations between the genetic and the salivary maps much like the series worked out by Bridges at the vg locus, which was reported in 1937-1938.

It is possible that M(S)10 is also associated with an inversion. Counts of over 3000 flies from a cross of M(S)10/l^t cn ♀ × l^t cn ♂ gave no crossing over between l^t and cn (light and cinnabar).

The other deficiency problem involves overlapping of "M(2)C" (Curry) and "M(2)B" (Bridges), both deficiencies for dumpy and Minute(2)z.

Salivaries of M(2)C were reported by Bridges (see Year Book for 1937-1938) as showing "a loss of the section of bands

from just to the right of the faint band in 24D to half through the 'shoe-buckle' set of four bands in 25A." It was reported as establishing a "valuable correspondence . . . between the bands of the salivary map and the locus dumpy, with its numerous alleles, at 13.0 in 2L." Salivaries of M(2)B have not yet been examined.

Crosses with M(2)C show that it is a deficiency for echinoid, fat, Gull, M(2)z, and dumpy, and is a lethal allele of M(2)B. The mutant echinoid is mapped at 11.0, and dumpy is mapped at 13.0. The deficiency therefore covers a distance of approximately two units on the genetic map.

M(2)B is a deficiency for dumpy, and is a lethal allele of M(2)z and l(2)comb-gap. Seriation on the map at present, which was only tentatively established, places the order of mutants to the right of dumpy as M(S)1, thickvein, lethal(2)comb-gap, Streak. The evidence here suggests that l(2)cg is immediately to the right of dumpy, and that the M(2)B deficiency extends farther to the right than the M(2)C deficiency. Neither deficiency includes thickvein or is lethal in combination with M(S)1 or Streak. Tentative evidence on the locus of M(S)1 places it farther to the right than any of the loci involved in this complex. In view of the probable misplacement of l(2)cg on the map, it is doubtful if its locus is at 15.0, as reported there. Consequently an estimate of the length of the M(2)B deficiency in terms of map units must await further data on this locus.

G, M(2)z, and some of the lethal dumpy alleles, under suspicion as possible deficiencies, were checked for pseudodominance with other loci, but none were lethal with any but a known deficiency, or showed deficiency for recessive mutants. For the present, therefore, they may be regarded as point mutations.

On the basis of the above evidence, the

limits of the two deficiencies, as determined genetically, may be represented as follows:

11.0	12.0	12.0+	12.9+	13.0	15.0-?
ed---	ft---	G---	M(2)z---	dp---	l(2)cg
					Df M(2)C
					Df M(2)B

When salivary studies of M(2)B have been made, it is possible that further

valuable correspondence between the genetic and the salivary maps may be established. Previous salivary studies on Gull (a possible deficiency for fat) and the lethal dumpy alleles were made before the discovery of M(2)C, when the dumpy locus was believed to be farther to the right on the salivary map. Studies on these mutants, if they involve aberrations, may be more fruitful when their approximate loci, in the salivaries, have been determined.

CONSERVATION

NEWTON B. DRURY, San Francisco, California. *Application of research to problems in conservation.* (For previous reports see Year Books Nos. 35-37.)

Point Lobos Reserve. With assistance of funds provided by the Carnegie Corporation of New York and administered by the Carnegie Institution of Washington, a basic publication is being prepared which will interpret to the public visiting Point Lobos the primary values protected in this reserve. Chapters will deal with geology, the flora and fauna, the historical background, aesthetic factors entering into the beauty and meaning of the landscape, principles involved in protection of primitive areas, and other matters brought out by the Point Lobos studies carried on for several years past by the Point Lobos Advisory Committee with funds provided by the Corporation and the Institution.

Dr. John C. Merriam has spent some time at the reserve in preparation of his contribution to this volume, dealing particularly with the significance of the Monterey cypress (*Cupressus macrocarpa*).

Under direction of Dr. Willis W. Wagener, Senior Pathologist, Bureau of Plant Industry, U. S. Department of Agriculture, studies have continued on the subject of the fungus disease known as cypress canker induced by the fungus *Coryneum cardinale*, which has assumed epidemic proportions in California. The fact that this infection has been discovered on planted cypresses within less than a mile of Point Lobos has led to aggressive protective measures. This year, again, a zone of territory surrounding the reserve has been checked for the presence or recurrence of the disease, and infected trees or branches have been removed. Spraying in the vicinity of

infections has also been resorted to, although this phase of the work is still in the experimental stage. With the cooperation of local agricultural inspectors and state park personnel, a record is being kept of all known infections and measures are being taken to eradicate them. Careful recheck of all specimens of Monterey cypress in the reserve failed to reveal examples of infection, but the recurrence of infections in near-by planted trees has emphasized the serious nature of this menace to the most distinctive feature of Point Lobos.

Dr. Herbert L. Mason and Dr. Charles M. Belshaw have completed the mapping of a number of selected plots in the ecological survey of the vegetation of Point Lobos Reserve. On these maps, which represent areas carefully surveyed and identified on the ground, appropriate symbols and colors indicate the position of the vegetation types, and in some cases individual plants.

Of this study, Dr. Mason says: "The selection of the plots was guided by a desire to determine the direction that natural succession was taking in the various plant associations, in the area. Hence the plots, wherever this is practicable, have been located where they will traverse boundaries of two or more contiguous plant associations. It will be desirable to check these areas at regular intervals to note changes that may be taking place. Experience will perhaps be the best guide as to how often this should be done. I would suggest that it be done perhaps twice in the first five years, then possibly every five years thereafter. I think that the first check

should be made this year to serve to point out any errors that might have been made in the originals. The second check could then wait two or three years.

"It should be pointed out that such a survey may be of great assistance in determining the management policy of the Point Lobos Reserve. Once it can be determined in which direction the succession of the various associations is going, steps can be taken to speed or to retard this succession as the wishes of the administration may indicate."

Two sets of botanical specimens gathered during the survey by the Advisory Committee, representing 300 species, have been mounted. One set is on file in the Herbarium of the University of California, and the other will be kept at Point Lobos for reference by those interested in the plants of the reserve.

Human values of redwood forests. With the aid of the fund of \$4000 made available by the Carnegie Corporation of New York, initial studies have been made of those features relating to the significance and aesthetic appeal of redwood forests in typical areas, particularly in Bull Creek Flat and Prairie Creek Redwoods, Humboldt County, Del Norte Coast Park, and Mill Creek Redwoods, Del Norte County. Dr. Merriam has been assisted in this work by Mr. Emerson Knight, San Francisco land-

scape architect, by Dr. Ralph W. Chaney, and by the writer. Cover type maps have been begun, and extensive photographic studies have been made as an aid to this project. It is believed that the study here involved, difficult though it be in that it deals so much with intangibles, if systematically pursued will result in a body of material which will aid in securing better appreciation of, and greater protection for, the highest values of the redwood forests now being administered by the state park authorities of California.

Old Monterey historical program. Impetus given by studies financed by the Institution has continued, the local community going ahead with formulation of plans for preserving the physical evidences of history at Monterey, and governing future development of the city in harmony with them. The Monterey Plan, based largely on research and planning in which Dr. V. A. Neasham and Mr. Emerson Knight took an important part, has been adopted by the city as to its major features. A gift has been made to the State of "the House of Gold," a stone and adobe structure of typical early Monterey architecture, erected by Thomas A. Larkin about 1845. This gift was undoubtedly encouraged by the success of the Monterey studies.

ECOLOGY

CHARLES ELTON, Oxford University, Oxford, England. *Research upon natural fluctuations in North American animal populations.* (For previous report see Year Book No. 37.)

This research is part of a series of inquiries designed to throw light on the course and nature of fluctuations among wild animals in the northern parts of North America, and has been supported by means of a grant from the Carnegie Corporation of New York, administered through the Carnegie Institution of Washington. The inquiries are being pursued along two complementary lines. On the one hand, the records of the Hudson's Bay Company and other sources are being analyzed in order that the history of some of these fluctuations during the past hundred years or more may be built up as a background to current events. On the other hand, current annual inquiries are carried on, which make it possible to map the state of abundance of certain species, and to follow changes from year to year.

Inquiries into past fluctuations. Mr. Elton continued the examination and coordination of Hudson's Bay Company records, both in the London archives of the Company, and with the material already accumulated in the Bureau of Animal Population at Oxford during the past 15 years. A comprehensive account of the fluctuations of fur-bearing animals in relation to rodents, such as mice and lemmings, in Labrador and Ungava (Quebec Peninsula) has been prepared for publication in 1940. This gives a continuous story of fluctuations during the past 60 to 100 years. The history of the 10-year cycle in snowshoe rabbits, and fur-bearers dependent upon it, for the past 110 years has already been partly built up from records of the Hudson's

Bay Company, though the material has still to be put in final shape, which will take several years.

The Canadian Arctic Wild Life Enquiry has been developed as a means of recording the changes from year to year in numbers of lemmings, arctic foxes, and snowy owls, and of outbreaks of sledge dog disease associated with the wild-animal fluctuations, in the Canadian Arctic region. The methods and results are explained in the report for 1936-1937 (see bibliography). A similar report for 1937-1938 has been prepared by Mr. Chitty for publication in the *Journal of Animal Ecology* in November 1939. Certain modifications in mapping technique have been made, which will, it is hoped, increase the objectivity of this picture of the changes. The inquiry is carried out through observers organized by the Canadian Government Northwest Territories Administration, and by officials of the Hudson's Bay Company.

The Snowshoe Rabbit Enquiry. This inquiry, done with the cooperation of the National Parks Branch Bureau of the Canadian Government and the Hudson's Bay Company and other organizations in Canada, and of the U. S. Bureau of Biological Survey, U. S. Forest Service, and U. S. National Park Service, in the United States and Alaska, is designed to record year-to-year changes in the numbers of the snowshoe rabbit (*Lepus americanus*) over a very large sample of its total range. The scope and results of this inquiry are described in the report for 1937-1938, prepared during the past

winter (see bibliography). Mr. Chitty handled the major part of the inquiry (the Canadian data), Mr. Elton being responsible for the United States and Alaska portions.

The Hudson's Bay Company is continuing its field observations upon the reproductive rates of snowshoe rabbits, at five posts in Canada, following a five-year plan drawn up by Mr. Elton, who will analyze the results. It is hoped to discover whether snowshoe rabbits show periodic fluctuations in their reproductive rates at different times in the 10-year cycle.

Mr. Elton was able, in the course of a research tour in the late summer of 1938, to visit the headquarters of nearly all the organizations concerned with these inquiries in Canada and the United States, and to discuss various questions with the officials there (this tour was not paid for from this grant).

In connection with all these inquiries, it has been found necessary to obtain

certain published reports from other countries, in particular the U. S. S. R., where exactly parallel research is being done, and where very similar fluctuations occur both in the arctic fox and lemming, and in the hares living in the forest zone. A certain number of translations of key Russian reports has therefore been obtained.

The main work of mapping both the current inquiries at Oxford has been done by Mr. D. H. Chitty, under the supervision of Mr. Charles Elton, who has undertaken a part of the snowshoe rabbit work, has handled the general organization of the inquiries, and is responsible for all the research on early records. Mr. Chitty received part of his salary from the grant, the rest of which has been spent on the expenses of materials, maps, photography, and certain relevant literature, and expenses of investigating archives in London, which include small payments for secretarial assistance, to Mrs. Mary Nicholson.

EMBRYOLOGY

ARTHUR T. HERTIG, Boston Lying-in Hospital, Boston, and Free Hospital for Women, Brookline, Massachusetts. *Research in embryological pathology*. (For previous reports see Year Books Nos. 36, 37.)

These studies have been continued with financial support of the Carnegie Corporation of New York, administered through Carnegie Institution of Washington.

Since the last report, studies have been continued on the pathogenesis of hydatidiform moles and the pathologico-clinical correlation in mature hydatidiform moles. A systematic search has been instituted for early normal human ova in uteri removed surgically for various therapeutic indications.

The latter studies have been facilitated by association as pathologist to the Free Hospital for Women in Brookline, Massachusetts, since July 1, 1938. During the course of the past year, the writer and Dr. John Rock, of this clinic, have succeeded in finding two early normal human ova having an ovulation age of about 11 days. These were sent to Dr. George L. Streeter of the Department of Embryology, Carnegie Institution of Washington, where they were faultlessly photographed and sectioned. They were reported briefly before the American Anatomical Association in April 1939 (*Anatomical Record*, vol. 73, no. 3, suppl. 2, pp. 26-27, 1939). It is believed that these specimens are the two youngest complete human ova in existence. They represent a period of early human development before the chorionic villi have been formed. A complete description of the two ova is nearly completed and will be published in an early issue of the *Contributions to Embryology*.

In the pathological laboratory of the Boston Lying-in Hospital a significant number of pathological ova have been studied which show sufficient hydatidi-

form change in their villi to justify the conclusion that they are transitional stages in the pathogenesis of mature hydatidiform moles from smaller "blighted" or pathological ova with slight hydatidiform degeneration in their villi. The latter specimens are common in spontaneous abortions (of which we have studied some 900 cases). The gestational age of these pregnancies is 10 weeks and that of the transitional moles 14 weeks, whereas the mature hydatidiform moles are of 17 to 19 weeks' duration prior to expulsion. Thus the mature mole would seem to be formed from a smaller potential mole that had, for some reason or other, been retained *in utero* for 7 to 9 weeks longer than usual. Corresponding proliferative changes of the villus epithelium accompany the progressive gross hydatidiform degeneration of the villus' stroma. A complete report of these changes has been accepted for early publication in the *Archives of Pathology*.

A preliminary pathologico-clinical correlation between the microscopic pathologic anatomy of hydatidiform moles and the clinical outcome of the patient has been completed in 82 cases. These have been collected over a period of five years from all over the country. Thirty-five cases diagnosed pathologically as benign have developed no subsequent malignancies and 39 cases diagnosed pathologically as potentially malignant have developed 7 malignancies, whereas of 8 diagnosed as malignant 7 subsequently justified this diagnosis. A more extensive study is in progress and more cases will be obtained before a final conclusion is reached.

GENETICS

BARBARA S. BURKS, Genetics Record Office, Cold Spring Harbor, Long Island, New York. *Studies of available data in connection with research projects in the field of human heredity.* (For previous reports see Year Books Nos. 36, 37.)

The following report has been submitted with relation to studies undertaken at the Genetics Record Office by Dr. Burks with support of funds granted by the Carnegie Corporation of New York to the Carnegie Institution of Washington.

Research has continued in the general directions indicated in the two previous annual reports, viz., search for linked pairs of traits; investigation of the nature, the mode of transmission, and the vulnerability to environment of traits, simple or complex; methodological studies, e.g. on the objectivity of ratings and diagnoses of traits; critical reviews of published studies. In addition, a study on the growth of monozygotic twins was completed, utilizing data available in the Harvard Growth Study records (courtesy of Professor W. F. Dearborn).

Dr. Elizabeth A. Graves served as research assistant during the summer of 1938, Dr. Ernest Dichter as field assistant during the spring of 1939, and Mrs. Frances Carlson as secretary and clerical assistant during the entire year.

A number of visitors have spent varying periods of time at the laboratory to study and discuss methods of collecting and analyzing human heredity data. Claude Shannon, of the Massachusetts Institute of Technology, arrived in June to spend the summer in theoretical genetics, particularly the formulation and solution of problems in terms of his original "index" algebra.

With respect to linkage studies: no instances of autosomal linkage in man beyond that indicated in a previous

report have appeared, although it has been possible to add to the accumulation of negative results—a necessary procedure in the laborious beginning of chromosome mapping. Thus, on the basis of data in the family records of the archives, and data gathered incidentally in field visits made during the past and current year to families in which myopia and tooth anomalies appeared, it has been possible to collate certain no-linkage groups of traits, viz.:

Myopia, hair color, finger curvature, mid-digital hair, taste for P. T. C.

Congenital tooth deficiency, eye color, finger curvature.

Short upper lateral, hair color, mid-digital hair, finger curvature.

The possibility has not been ruled out that linkage exists between factors for myopia and for eye color; further data are needed to check upon possibly positive results obtained from the archives and from a field study.

One of the most interesting outcomes of the several field studies conducted primarily for the linkage search was the discovery of an easily diagnosed trait, inherited probably as a simple dominant, having a sufficiently high gene frequency to make it useful as a "test factor." The trait has been called "hypoplastic" or "short upper lateral"; it may appear either unilaterally or bilaterally. Somewhat over 40 per cent of an unselected high-school population were affected; hence the gene frequency was estimated at about 25 per cent. In figure 1 the trait is illustrated through sketches of

the four upper incisors of each of ten siblings.

The degree of resemblance of unselected sibling pairs with respect to the trait (correlation of 0.33) so clearly suggested the presence of a dominant factor that check data were gathered through a field follow-up of the largest families represented by the *propositus* cases. The results were corroborative; siblings showed the trait in numbers very closely corresponding to theoretical expectation. Few of the parents could be diagnosed because their teeth were so often

with hair color in an earlier study. ("Peg" teeth or "rice" teeth, on the other hand, are often genetic equivalents of tooth deficiency.)

Aside from the advance in human genetics which merely the discovery of linkage groups will represent, the ascertainment of pairs of traits containing linked factors offers a means for analyzing the genetic character of traits for which the usual techniques of pedigree analysis are not available or not adequate. In the case of the autosomal linkage earlier reported (Year Book

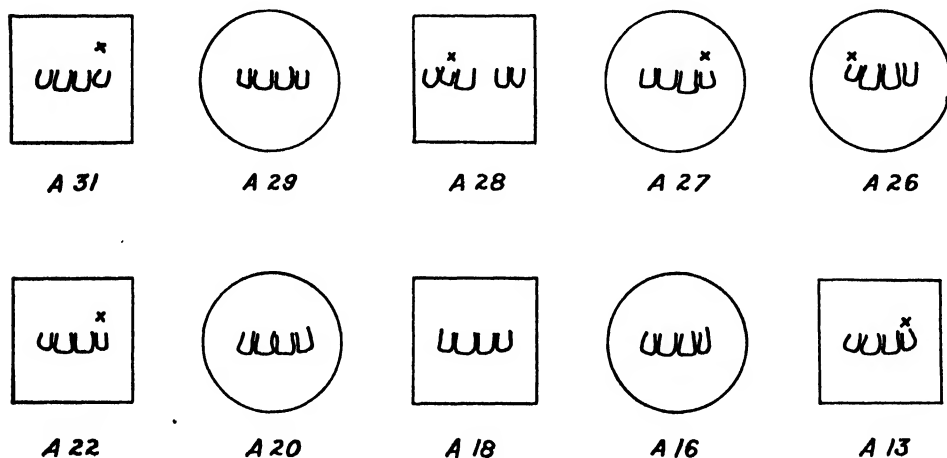


FIG. 1. Short upper lateral incisors occurring in 6 of 10 siblings

missing (extracted), or changed from the original structure through wear, extensive caries, or repair. In so far as parents could be included in the study, their tooth structure was not inconsistent with the hypothesis of a simple dominant gene.

A further follow-up is planned, using X-ray techniques, to investigate the relation of the trait to other structural characteristics of dentition. The negative test for linkage between short upper lateral and hair color rules out at the same time a genetic connection between the trait and congenital tooth deficiency, since the latter was found to be linked

No. 36 [1936-1937]) between hair color and congenital tooth deficiency, the "linkage table" showed peculiarities of structure which were inconsistent with some hypotheses as to the transmission of hair color, but consistent with certain others. This result was taken as a lead for a new study making use both of family records in the archives, and of data collected in the field, to provide a basis for selecting the hypothesis that would correspond most closely to the total array of facts.

This study is still under way, as is a companion study on the objectivity of classification of hair colors. Both studies

merit considerable time expenditure, since one of the leading tasks at the present stage of work in human genetics is to find "test factors" for use in linkage studies, that is, traits which are widely distributed in the population, simple to diagnose, and inherited through a fairly simple mechanism.

A study of the anthropometric and mental growth records of the monozygotic twins occurring among the Harvard Growth Study records has been pending for some time. This was completed ahead of still other pending studies in response to a request for material suitable for the 1940 Yearbook of the National Society for the Study of Education: *Intelligence: its nature and nurture*. A paper summarizing the results of the study was also prepared for the April meeting of the American Philosophical Society.

Although correlation studies have never shown more than a low positive inter-correspondence between mental and physical growth processes, such an approach could not be expected to do more than suggest the presence of growth patterns if these show appreciable complexity and individuality from person to

person. Through the use of monozygotic pairs of twins, however, it should be possible to ascertain, even without knowledge of the "normal" or "constitutional" developmental route of either member of a pair, whether or not perturbations in growth, as shown by a temporary or permanent divergence in the corresponding growth curves of the twins on some particular trait, are actually part of a growth disturbance transmitted to other structures or functions. While the proposed twin-comparison method is aimed at an interpretation of growth fluctuations which are nongenetically determined, it should at the same time give light upon the nature of growth interrelations which do have a constitutional basis, since it is the *patterning* of growth processes which is under scrutiny.

The study has resulted in evidence for fairly striking relationships between shifts in the growth rates of intelligence and in certain anthropometric traits, especially iliac width and trunk length. Thus it supports an organismic theory in which structures and functions, each having its own characteristic secular trend, are nevertheless closely related with respect to lag and acceleration.

CHARLES B. DAVENPORT, Cold Spring Harbor, Long Island, New York. *Investigation on child development*. (For previous reports see Year Books Nos. 34-37.)

During the past year the writer has continued his work of analyzing the results of many years of repeated observations on the development of individual children. A paper was published by the American Philosophical Society entitled "Post-natal development of the human outer nose." This analyzed the growth of five absolute dimensions and the changes in eight ratios. A comparison was made of growth in individuals and especially in twins and cases of more marked defect in growth.

In the year under review work has been concentrated on the development

of the head, including the cranium, the face, and, among other things, the migration of the eyes. A preliminary statement was read before the American Philosophical Society on "The living skull." In this paper there were pointed out the remarkable changes in proportions of the cranium during the first few days after birth, which are due to the reconstruction of the head after distortion during parturition.

Relative development of the part of the head behind the external ear opening changes during childhood. Thus, the proportionate head length behind the ear

reaches a maximum during the first few months after birth, tends to decrease until about $2\frac{1}{2}$ years, then increases temporarily to about 4 years, and thereafter decreases again until adolescence. These changes in the proportion of the head behind the ears are partly due to the migration of the ear opening itself, which tends to move backward and downward during juvenility.

As to face development, the great changes in the face during early childhood are largely due to the enlargement of the maxillary sinus and cutting of the teeth, especially the molars. By the growth of these parts the face becomes increased not only vertically but also in horizontal direction, leading to a greater prominence in the jaws.

The eyes, which when first laid down are removed by a large angle from each other, being placed upon the sides of the head, tend during intra-uterine life to migrate so as to look forward. The process, however, is not completed at birth, but continues until puberty, in consequence of which the angle subtended by the two axes of the orbits diverging from the inter-ear line diminishes from about 49° at birth to 41° at adolescence. Thereafter the angle increases slightly.

A special comparative study was made between average variation inside of families and variation between families. Variation inside of families is markedly less than the variation of the general mean of these families, which is evidence of the presence of genetical factors determining every stage in the development of the head.

Especial consideration is given to changes in the form of the cranium in the first year of life as a result of the way in which babies lie in the crib. Studies made by others on this subject indicate a certain amount of distortion according to the posture in the crib. However, this distortion seems to be

largely smoothed out by maturity. A study of the cranial dimensions of a number of cases of children bedridden from birth does not show at puberty any such enlargement of the vertical axis as had been noted in babies resulting from the way in which they lie in bed. This experience with older children seems to indicate that any such vertical distortion becomes smoothed out by maturity. However, in the case of children whose heads have been distorted by binding during infancy and early childhood (as in some tribes of North American Indians) the typical head form is never completely restored.

Through a series of repeated roentgenograms taken at Letchworth Village on the children who are being studied there, it was possible to follow the development of the frontal sinus during the period when it is undergoing its most rapid development. The influence of such development upon the form of the superciliary arches and on the length of the cranium seems to be marked.

A paper entitled "The genetical basis of resemblance in the form of the nose" was prepared for the *Festschrift* to Professor Otto Reche. Attention was called to the marvelous resemblance in the form of the nose in identical twins and sometimes members of the same family who are not twins.

A paper on the changes in basal metabolism of the children that were studied at Letchworth Village during adolescence has been prepared with the valued technical assistance of Miss Olive Renfroe, of Letchworth Village, and Mr. Wilfred D. Hallock.

To make possible the completion of the studies on the head and extremities, financial assistance has been received not only from the Carnegie Institution but also from Mr. Samuel S. Fels, the Trustees of the Mary W. Harriman Estate, and the American Philosophical Society.

Especial thanks are due to the officials of Letchworth Village for the extraordinary opportunities that they have afforded for

gathering statistics and, now that that work is ending, for further assistance in preparing copy for publication.

TH. DOBZHANSKY, California Institute of Technology, Pasadena, California. *Studies on the genetic structure of natural populations.* (For previous report see Year Book No. 37.)

These studies have been continued with aid of a grant from the Carnegie Corporation of New York to Carnegie Institution of Washington.

Classic studies on organic variation have been of necessity restricted to observations on the morphological and physiological characteristics of living beings. In recent years it has become increasingly evident that the amount of such visible variability is far exceeded by that of the hidden variation in the hereditary endowment of the organisms. This concealed variation is due to the occurrence of numerous recessive mutant genes, usually present in natural populations only in heterozygous condition, and of chromosomal rearrangements, especially of the inversion type. Although this situation is likely to be encountered in most sexually reproducing and cross-fertilizing forms, including man, it has been, for technical reasons, studied mainly in the small flies belonging to the genus *Drosophila*.

In the population samples of *Drosophila pseudoobscura* coming from the mountain ranges of the Death Valley region of California and Nevada, 14.96 ± 0.82 per cent of the third chromosomes proved to contain lethal or semilethal genes. In the populations of the same species collected in Mexico and Guatemala the frequency of such chromosomes is higher still, namely 30.00 ± 2.82 per cent (28.05 ± 3.35 in Mexico and 34.21 ± 5.20 in Guatemala). Among the chromosomes free of lethals, about 40 per cent contain genes unfavorable for the viability of the carrier, but not classed as semilethals in view of the

lesser extent of their effects. A not exactly determined, but certainly appreciable, proportion of the chromosomes have genes modifying the development rate, or causing one or both sexes to be sterile. Three types of the Y-chromosome have been found, one restricted to Guatemala, and two occurring in Mexico as well as in the populations from the western United States and Canada. The variations in the gene arrangement in the third chromosome have been reported upon previously (see Year Book No. 37 [1937-1938]).

The rôle of the concealed hereditary variability in the economy of the living species must now be examined. A gene that is completely recessive produces visible effects only when, owing to a chance meeting of two sex cells carrying it, a zygote is produced in which this gene is present in duplicate. Experiments bearing upon this problem are best done with lethals, since the detection of the latter is an entirely objective procedure, involving no personal equation. The frequency of the zygotes receiving third chromosome lethals from both parents must be equal to the square of the frequency of the lethal-bearing chromosomes, that is, 2.25 per cent for the Death Valley populations and 9.0 per cent for the Mexican and Guatemalan ones. Since, however, zygotes containing two lethals are inviable only when these lethals are allelic, the necessity arises of determining how frequently such allelic lethals are encountered in natural populations. A total of 123 third chromosome lethals found in eleven different population samples from the

Death Valley region were analyzed. For this purpose, intercrosses were arranged of flies containing every one of the 123 lethals to practically every one of the remaining 122. The appearance, versus nonappearance, of flies carrying the two third chromosomes tested shows whether or not the lethals in question are alleles.

A fact of some significance has emerged from these experiments: different lethals recovered from a population inhabiting a given locality prove to be allelic more frequently than do lethals coming from different localities. Among 772 crosses where individuals were produced carrying two lethals from the same locality, there were 24 crosses involving allelic lethals. The corresponding figures for the interlocality crosses are 20 alleles out of 5460 crosses. This difference is statistically very reliable. In one of the localities the same lethal has been found four times among 55 chromosomes tested (including those free from any lethal), and in another locality a lethal was encountered also four times among 124 chromosomes. It is reasonable to assume that allelic lethals found in different localities are mostly independent in origin, while the alleles recovered from the same population are, on the contrary, the descendants of a single mutant. It follows, then, that lethals can accumulate within a population. Such a result can hardly be brought about by the action of natural selection. Indeed, even if the assumption is made that some of the lethals produce nondeleterious effects in heterozygous condition (such an assumption has no support in experiments, see below), it would remain obscure why certain lethals are selected in one locality while different ones are favored in another locality with apparently identical environment. Accumulation of lethals in the populations studied is almost certainly due not to selection but to random variations in the gene frequencies within populations of a limited effective size

(the phenomenon postulated on the basis of theoretical considerations by Sewall Wright).

Following a suggestion of Professor A. H. Sturtevant, an attempt was made to compute from the above data the rate of elimination of lethals under natural conditions. In populations from the Death Valley region about 3 per cent (24 out of 772) of the zygotes carrying two lethals contain allelic ones, and hence are inviable. Now, since zygotes with two lethals make up 2.25 per cent of all the zygotes produced, about 0.0675 per cent of the latter (0.03×0.0225) are lost to the species. A similar elimination rate constant cannot be calculated for the Mexican and Guatemalan populations because the frequency of the allelic lethals in them is unknown, and the data of this kind obtained for the Death Valley samples cannot be extrapolated. A comparison of the elimination rate of lethals with the rate of their origin *de novo* in the Death Valley populations is discussed below.

The order of magnitude of another constant may also be inferred from the data on the frequency of allelic lethals in different populations. This is the number of loci in the third chromosome of *Drosophila pseudoobscura* that mutate to produce recessive lethals. In a sample of 105 lethals from eleven localities in the Death Valley region, 68 lethals were found once each, 17 occurred twice each, and 1 three times (it being immaterial in this case how many times these lethals were encountered within a locality). Two assumptions must be made to make calculations possible, namely, that the allelic lethals found in different localities are independent in origin, and that the mutation rates producing lethals in different genes are alike. The first of these assumptions seems sound enough, but the second is more dubious; if it is incorrect, that is to say if some of the genes give lethal mutations more fre-

quently than others, the figure for the number of mutable loci arrived at will be lower than the actual one. The necessary formulae for the calculations were kindly supplied by Professors Morgan Ward, Sewall Wright, and H. J. Muller, and the minimum number of mutable loci in the third chromosome was found to lie between 250 and 251. If all lethals were distributed uniformly in the populations, in the Death Valley region each lethal must be present in $14.96:250=0.06$ per cent of wild chromosomes. As indicated above, certain lethals are much commoner in some of the populations, hence the distribution of lethals is not uniform. The alternative explanation, namely that the lethals which were found to be frequent in some populations are those with a high mutation rate, is excluded by the fact that these same lethals may not be found at all in different populations.

As indicated above, the frequency of lethal-bearing third chromosomes is twice as great in the Mexican and Guatemalan populations as it is in the populations from the Death Valley region. Such a difference may be due either to the spontaneous mutation rate producing lethals' being four times greater in the former than in the latter region, or else to the effective sizes of the breeding populations' being unlike in the different parts of the distribution area of the species (in this case, greater in Mexico and Guatemala than in Death Valley). The inherent mutation rates in the third chromosomes of Mexican and Guatemalan origin and in those of Death Valley origin were therefore determined. The technical detail of these very laborious experiments will be presented elsewhere. Here it may be stated that in the 13,472 chromosome-generations of the Death Valley material 40 new lethals were obtained, while in the 7699 chromosome-generations of the Mexican and Guatemalan lines there were found 25 lethals. Hence,

the mutation rates are 0.297 ± 0.032 and 0.325 ± 0.044 per cent respectively. The difference is certainly not significant, and combining the data we find the mutation rate to be 0.307 ± 0.025 per cent, determined in 21,171 chromosome-generations. With 250 mutable loci, this means a mutation rate of 1:81,425 per locus per generation.

The mutation rate may be compared with the estimate of the elimination rate obtained above (0.307 and 0.0675 per cent respectively). It is clear that in any population which is approximately at an equilibrium the mutation and elimination rates for lethals, or for any other kind of genetical change, must be alike. Yet our determinations of the two values show them to be decidedly different, the significance of the difference being beyond question despite the rather large probable errors. Such a discrepancy naturally indicates that some of the assumptions made in our work are untenable. One of the possibilities is that the lethals have semidominant deleterious effects, and hence are eliminated not only when homozygous but when heterozygous as well. Experiments designed to test this possibility have so far given consistently negative results, both where the "natural" and where the newly arisen spontaneous lethals were involved. Another possibility is that the samples of the flies taken in the Death Valley region did not represent single panmictic populations, and that, consequently, the true elimination rate may be much higher than the computations indicate. This amounts to saying that, in *Drosophila pseudoobscura*, a population inhabiting even a very small territory does not represent an elementary breeding unit, and that a hitherto unsuspected amount of local inbreeding takes place. Experiments now in progress have been designed to test the hypothesis just outlined, as well as certain related problems.

GEOPHYSICS

ARTHUR L. DAY, Bethesda, Maryland. *Studies of the hot springs of New Zealand.*

The hot-spring region of New Zealand has an especial interest at this time because of the fact that the Geophysical Laboratory has lately completed a seven-year study of the hot springs of Yellowstone National Park. It happens that New Zealand shares with the United States and Iceland the distinction of containing the only known regions in which major hot-spring activity, including geysers and boiling springs of all types, has been found. It also happens that relatively little scientific study has hitherto been given to these more distant regions, and it is hardly possible, without comparative studies of the kind here contemplated, to be sure that conclusions drawn from observations in one locality have general application.

It has long been noted that these major hot-spring activities occur in country now or recently volcanic, and geologists have quite generally admitted the probability that the ultimate source of heat which finds its outlet in spectacular boiling springs and geysers is directly associated with volcanism. Nevertheless some of the conclusions of earlier years have been shown to be overhasty, probably because they have not been supported by direct and detailed observation. For example, it has been shown, quite contrary to earlier beliefs, that hot springs do not differ from cold springs merely because surface water in its normal circulation has encountered hot rocks instead of cold ones. Hot rocks under such conditions, even if adequate for a short time, would quickly cool down, for their heat conductivity is low. In Yellowstone Park, for example, Old Faithful geyser alone would require all

the heat from two square miles of initially red-hot rock surface to maintain its present activity for a single year. Observation on the ground, however, quickly shows that the deposition of silica about the opening of this geyser must have required many thousands of years, at the present rate of such deposition, to reach its present development. Also it is true that there are some seventy major geysers in the same basin with Old Faithful, not to mention some hundreds of boiling springs, all of which must share the local heat supply. This condition, when accurately observed and measured, effectually disposes of the adequacy of hot rocks to account for the continuing hot-spring activity of the Upper Geyser Basin in Yellowstone Park.

Another problem is offered by the variations in the hot springs themselves. There are areas in the Yellowstone Park, for example, in which the springs are deep, wonderfully clear, and alkaline, and are depositing silica sinter out of a dominantly chloride solution, while others covering wide areas are conspicuously acid, turbid, and shallow with comparatively little mineral (sulphate) deposition. Notwithstanding this difference in the springs, the rocks in which the waters circulate are all of rhyolite of nearly uniform composition. Observations in New Zealand have now shown that practically the same condition prevails there. It is a conspicuous fact that geysers in both countries are found among the alkaline springs and not among the acid (sulphate) ones. There is therefore a physical problem, to discover and account for a continuing source

of heat competent to maintain these great hot-spring areas over periods of thousands of years, and again a chemical problem, to account for the conspicuous chemical differences among the springs themselves.

Observations in Yellowstone Park had provided a plausible theory accounting in detail for both of these situations. Whether or not it would be found to apply in the other hot-spring regions of the world and so attain to general significance was the problem posed by the investigation in New Zealand in 1937, and studies in Iceland which are still going on under a grant from the Carnegie Institution to Professor Tom. F. W. Barth, now of the University of Oslo, Norway, but formerly on the staff of the Geophysical Laboratory.

Observations by the writer in New Zealand during 1937 served to fix many details of comparison of the temperatures and physical behavior of the hot springs of New Zealand, to establish their apparent relationship to volcanic sources of energy, and to classify them in groups according to physical characteristics and chemical content. Collections of waters and gases were also made for subsequent study and comparison with corresponding observations in the Yellowstone Park. However, since it was not practicable to transmit such collections to the Geophysical Laboratory in Washington for study because of the long distance and the probability of chemical alteration en route, and perhaps also because it was deemed desirable to endeavor to arouse in New Zealand an active interest in these hot-spring problems and perhaps some initiative to carry on a much more thorough local study than was possible for a stranger during a short visit, arrangements were made to have these samples studied in the Government laboratories of the Department of Scientific and Industrial Research in Wellington. The

efforts of the past year have been directed toward the chemical study of these samples, the results of which have been coming in from time to time during the year and are being studied here.

The present hot-spring activity in New Zealand is concentrated in a zone extending approximately north-northeast across the North Island from the volcano Ruapehu to and including the volcano known as White Island, which just emerges from the sea about fifty miles off the coast. Because of license limitations restricting the fishing boats, White Island volcano, which is uninhabited, was not accessible to the writer during his visit in New Zealand, but during the past year, with Government assistance, and with aid of a grant from the Carnegie Corporation of New York to Carnegie Institution of Washington, Dr. Patrick Marshall, Government Geologist, and Dr. Stuart Wilson, Government Chemist, twice succeeded in visiting the island and in making observations and collections there. The next step in the investigation will therefore be concerned with the laboratory study in Wellington of these additional collections of minerals, waters, and gases.

It is of some interest to note in passing that in the hot springs of White Island have been found the highest concentrations of free acid ever noted in a hot spring. In one of the springs something like 10 per cent of the fluid contents was found to be made up of mixed hydrochloric and sulphuric acids. A fragment of sheet zinc immersed in the spring was dissolved immediately.

One of the major conclusions reached in the Yellowstone Park investigation was that the source of energy is magmatic heat transmitted by the magmatic gases set free during the crystallization of the magma and percolating upward through joint cracks in the rhyolite until circulating ground water is encountered near the surface. Investigations at the

Geophysical Laboratory have shown that these magmatic gases contain over 90 per cent of superheated water vapor, which, upon encountering surface water, gives up its superheat and latent heat to the water and so provides a continuous energy supply to the hot springs and geysers. Substantiation of this conclusion is found in the fact that the hot springs contain such elements as boron, sulphur and arsenic, chlorine and fluorine, which are common to magmatic gases so far as known, but are found only in traces, or not at all, in the rhyolite and the surface waters in contact with it. Preliminary results from New Zealand appear to confirm this relationship there and so help to generalize the conclusion that this is the manner of transmission of volcanic energy to the surface waters.

Again, in the Yellowstone Park the conclusion was reached that the deep alkaline springs and geysers were confined to the valley bottoms where drainage water circulates to greater depths and so reaches the zone of hot magmatic gases at a deeper and hotter level than is the case with hillside springs of shallow drainage. Hence it happens that a greater volume of heat is transmitted to the valley-bottom drainage and the acid components of the magmatic gases become more completely neutralized through reaction with the feldspars of the rhyolite than is the case in shallow hillside springs. This fact appears to be firmly established in the enormously greater *quantity* of heat found in the valley springs and geysers and their generally alkaline reaction. This relation also appears to be characteristic of the New Zealand areas.

The acid (sulphate) springs in Yellowstone Park are practically confined to hillside areas in which the penetration of ground water is shallow and the magmatic gases reach these waters only after a much longer excursion to much higher

levels. The gases (notably hydrogen sulphide) are not all neutralized in passage, and surface springs in such areas are found to be acid, turbid, and below boiling temperature. It is altogether conceivable and, in rare instances, is established by observation both in Yellowstone Park and in New Zealand that magmatic gases may reach the surface in hillside localities without encountering ground water in sufficient quantity to condense the steam. This results in steam fumaroles containing some 95 per cent of water vapor and a remainder of carbon dioxide and such of the other volatile components of the magma as may not have been neutralized or condensed in their long passage through the surface rocks.

The chief distinction which has thus far appeared between the Yellowstone and New Zealand hot-spring areas is the fact that lines of demarcation between sulphate and alkaline areas are less well marked and mixed waters more common in New Zealand than in the Yellowstone. Topographical features determine the runoff and so are important factors influencing the local depth of circulation of the meteoric waters, but in New Zealand they are by no means the only such factors. Rainfall is approximately double that in Yellowstone Park, and the land surface of practically all the hot-spring areas and adjacent country is covered to a depth of several hundred feet at least with the products of geologically recent volcanic activity—ash, boulders, and scoriaceous material deposited from the air, bedded and sometimes bonded in layers, porous or tight according to the temperature of the mass when it fell. Such surface conditions provide a much freer subsurface circulation for ground water or rising magmatic gases than the thick rhyolite flows of Yellowstone Park, in natural consequence of which both hot springs and geysers appear to be less stable both in

location and in habit than those in this country.

The great White and Pink Terraces and associated Rotomahana geysers of the early eighties might have offered serious exception to this conclusion at that time, but the great eruption of Tarawera in 1886 completely destroyed these monuments, and a lake of warm, highly mineralized water three miles long and perhaps half as wide now occupies their place.

Likewise the greatest geyser of record

(Waimangu, 1500 feet) appeared some years later (1902) in the very rift opened by this eruption, played in a most spectacular manner for some three years, and disappeared without leaving even a pool to mark its location today.

It seems at the moment quite safe to conclude that contemporary volcanic activity accounts for most of the differences noted either above or below ground between the hot-spring phenomena of New Zealand and those of Yellowstone Park. These studies are being continued.

METEOROLOGY

V. BJERKNES, University of Oslo, Oslo, Norway. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics to practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5-37.)

Investigations. Professor J. Bjerknes and Dr. E. Palmén have finished another aerological investigation similar to that mentioned in the previous report. The observational material this time was collected by observers in many European countries together during the week of December 13-18, 1937. The weather situation during the selected week was rather complex and devoid of big perturbations. The results are therefore less "thrilling" than before, but they have, of course, increased our knowledge of the nature of weak and degenerated atmospheric perturbations.

Redactional work. It was said in the last annual report: "It may be hoped that the preliminary manuscript of the remaining chapters of part III [atmospheric dynamics] will be ready in the course of the coming year." Thanks to the tenacious activity, especially, of Dr. C. L. Godske, the forecast has this time proved to be almost correct. At present the text has no lacunae, except in chapter 20, where some small parts will

most naturally be written in conjunction with the drawing of the maps, which is still to be done.

The work will consist of the following parts: part I, "Atmospheric statics"; part II, "Atmospheric kinematics"; part III, "Atmospheric hydrodynamics"; part IV, "Atmospheric 'models'"; part V, "Synoptic meteorology." This division into five parts gives a more logical structure than the earlier division into three, but it is still possible for the sake of practical handling to make only three volumes, the first comprising parts I and II, the second part III, and the third parts IV and V.

What now remains to be done does not seem much, but it is hardly necessary to emphasize the fact that the finishing touches on a long manuscript with all its illustrations and tables are the most difficult part of the work to estimate as to the length of time that will be required. We shall aim at the quickest possible accomplishment of the remaining task.

NUTRITION

E. G. RITZMAN, University of New Hampshire, Durham, New Hampshire. *Co-operative researches on the nutritional physiology of the adult ruminant.* (For previous report see Year Book No. 37.)

A study of the metabolism of dairy cattle during growth, reported on last year, has been continued. This second year with this series of experiments brings the study up to the time when they are due to drop their first calves.

A total of 24 basal metabolism experiments and 12 complete balances of the ingo and outgo of nitrogen and of energy were carried out in connection with this study on dairy cattle. At about 8 months of age, when the experiments were begun, the basal was very high (average 13,300 cal. per 500 kg. weight), but about 12 months later this had dropped 25 per cent. From this period on to date, various stages of pregnancy indicate that up to 4 or 5 months of gestation this condition does not materially affect the basal metabolism, but that at a month before parturition (8 to 8½ months pregnant) the basal metabolism is about 30 per cent higher than in the nonpregnant heifers. The extent to which these values may be affected by seasonal variations in metabolism due to other factors is as yet not clear.

A beginning has been made this year in determining the basic cause of these seasonal variations in basal metabolism by a study of the influence of light in this respect. This study has been begun with the consulting cooperation of Dr. John W. M. Bunker, physiologist, of the Massachusetts Institute of Technology, and Dr. Milton O. Lee, endocrinologist, of the Harvard Medical School.

The accessory lighting installation as designed by Dr. Bunker consists of 42 Hygrade luminescent tubular lamps ar-

ranged in five banks on ceiling, front wall, and two side walls. Each lamp has a consumption of 20 watts and a lighting efficiency approximately twice that of a Mazda bulb of equivalent wattage. The arrangement is controlled by a 10-circuit cyclic contactor which provides for a gradually increasing intensity of light, beginning with two lamps at 4:30 A.M., until 11 A.M., when all lamps are on; and they go off in reverse order hourly until 7:30 P.M., when the last two go out. The percentage change in illumination follows in this quite closely the curve for outdoor sunshine in June at Cleveland, Ohio, which is of approximately the same latitude as Durham, New Hampshire. The illumination, while much greater than that in a well-illuminated office, appears to the observer as neither brilliant nor irritating; as measured by Dr. Bunker, there were found to be 70 foot-candles at the level of the eyes of the standing animals, and 30 foot-candles at their eye level when they were lying down.

It has been repeatedly stated¹ that the challenging result of our extensive researches on metabolism over a period of nearly twenty years is the extraordinary lability in basal metabolism and particularly the very marked trend toward a seasonal influence, with a low level dur-

¹ Francis G. Benedict and Ernest G. Ritzman, The lability of the basal metabolism of the dairy cow, *Science*, vol. 81, no. 2105, pp. 416-417 (May 7, 1935). Ernest G. Ritzman and Francis G. Benedict, The nutritional physiology of the adult ruminant, *Carnegie Inst. Wash. Pub. No. 494* (1938). Ernest G. Ritzman, Lability of the basal metabolism of the dairy cow, *New Hampshire Agric. Exper. Sta., Scientific Contr. No. 48* (1935).

ing the late winter months (February and March) and a high level in late May, June, and July. Since the effect of temperature as a cause is obviously ruled out, the influence of light (by stimulation of endocrine activity) was naturally suggested as an alternative.

Dr. Bunker has pointed out numerous relations between visual stimulation in reptiles, birds, and rodents and the physiological responses attributed to such stimulation. These phenomena—such as the expansion of pigment bodies in the skin of the frog in response to pituitary activity which can be aroused by visual sensation; the early maturity of gallinaeous birds when illuminated for a few weeks by moderate intensities of Mazda lamp emissions; the ovulation of the pigeon when the male bird is in sight and at no other time; the increase of ovarian activity in mature birds which seems to be referred to increased hours of visual light; and the phenomenon of a yearly sexual cycle in certain rodents—are dependent apparently upon light. It was judged that photochemical effects due to particular wave lengths of radiations upon the skin of animals constitute phenomena of a different category. Whether or not solar radiation will be found to have an effect upon basal metabolism can hardly be predicted, but since basal metabolism is governed in part by endocrine activity and since already effects on certain endocrines have been shown to follow stimulation of the visual sensory apparatus, it seemed reasonable first to investigate whether that type of stimulation can be shown to result in any effect upon the basal metabolism of the ruminant, or upon any aspect of its functional metabolism, as for instance the reproductive functions.

Eight heifers were used in this study, four being subjected to this accessory illumination, and four being kept in stalls from which most of the light was excluded by heavy shading of win-

dows. The illumination around the dark stalls was so low that with a reasonably sensitive illuminometer no reading could be recorded. Owing to the delays in getting delivery of the lamps, the experiment could not be begun before the middle of January, when the animals had already been subjected to the normal shortage of natural daylight for about three months. Consequently when their metabolism was first measured the animals receiving the light treatment had been subjected to this condition for only 45 days or less, and their average basal metabolism was about the same as that of the cows receiving very little daylight. After the experiment had been continued up to about 70 days the basal metabolism of the darkened cows remained essentially the same (increase 2 per cent), whereas the animals with extra lighting showed an increase of about 10 per cent in basal heat production. Analysis of blood samples taken from these heifers when fasting showed material variations between individuals, but this bore no relation to the light treatment. Likewise the nonprotein nitrogen, calcium, and inorganic phosphorus constituents of the blood were very uniform throughout. While the data so far suggest an increase in metabolism as an effect of longer exposure to light intensity, the result can be regarded only as tentative, and it seems advisable that a series should be carried out in which this extra lighting is applied as early as October, when the length of natural daylight begins to wane.

A number of gas check tests and experiments have been carried out with the mask and apparatus designed to measure the energy expended by the horse during work. The check tests with carbon dioxide gas show a recovery of 99.2 per cent. The experiments with the horse have so far been of a purely preliminary nature, to perfect and standardize technique of procedure.

Twelve actual experiments in which this mask and apparatus were used on a draft-type horse (gelding) weighing 650 kg. (1433 lb.) have so far been carried out. The first trial with the mask was carried out with the horse quietly standing, and this was checked with a metabolism measurement on the horse quietly standing in the respiration chamber. The results (computed to 24-hour basis) were respectively (mask) 16,760 cal. and (chamber) 17,060 cal. A sequence of trials with the mask were then carried out on a flat-surfaced road, in which the energy expenditure was first measured for a 10-minute period while standing. This was followed after a brief rest period by a similar measurement while walking, followed by a further measurement, after a brief rest, while trotting. The results, given as calories per hour, were as follows (walk and slow trot measured over 1 mile distance, fast trot $\frac{1}{2}$ mile distance):

Road work	1st trial	2d trial	3d trial	4th trial
Standing	698	816	.....	804
Walking	2725 *	2322 †	2717 *	1967 †
Trotting:				
5 mi. per hr.		3540	3841	3882
10 mi. per hr. ....		.....	5565	4620

* Very fast walk.

† Slow, steady walk.

So far as we are aware, only one other series of experiments is on record in

which the energy expended by the horse in action has been measured.² This was at a walking gait (85 m. per minute) and pulling against 45 kg. resistance. Unfortunately no means was apparently available for checking the accuracy of this apparatus and procedure. The present experiments are, so far as we know, the first on record in which the energy expended by the horse at a gait faster than a walk has been measured. The gratifying feature of these attempts is primarily the fact that this mask and the peculiar technique involved have been demonstrated to be dependable, thus opening an entirely untouched phase in the study of energetics.

A series of monthly experiments were carried out during the year on five Chester White pigs to determine the basal metabolism during growth. The comparative basal metabolism of this species is of interest because of its relatively rapid growth and early maturity. Thirty-five separate metabolism determinations, beginning at 27 days of age and up to 241 days, have so far been made. This work is being continued.

² Wilhelm Berkoff, Untersuchungen über den Energieumsatz von Warmblutpferden und dessen Beziehungen zu morphologischen und physiologischen Merkmalen, Ztschr. f. Tierzucht u. Zuchtungsbiol., vol. 42, no. 1 (Oct. 1938).

H. C. SHERMAN, Columbia University, New York, New York. *Research on influence of nutrition upon the chemical composition of the normal body.* (For previous reports see Year Books Nos. 32-37.)

Our previous research, in showing the nutritional improbability of already-adequate food supply, with far-reaching effects upon the life history, gave new significance to the question how far science can influence for the better the internal chemistry of normal individuals.

Hitherto it has been thought that the chemical composition of the normal body is something rather rigidly specific. The discovery of certain age and sex differences, and the matter-of-fact recognition

of variations in the amounts of such inactive stored material as fat in the animal and starch in the plant, has hardly affected the rigidity of the general view that all we can do about our internal chemistry is to prevent or cure departures from the normal. That "the normal" is not merely a point or a line, but rather an area or a zone, and that the differences within this area or zone, while partly due to inherited constitution, are also largely due to food factors

which we are now learning to recognize and control, is perhaps the most fertile and promising thought in the present-day science of nutrition. It has been possible to undertake such studies with aid of a grant from the Carnegie Corporation of New York through the Carnegie Institution of Washington.

Having found that at least three of the chemical factors in nutrition—calcium, vitamin A, and riboflavin (formerly called vitamin G)—each exhibits a wide zone of difference between the minimal-adequate and the optimal level of nutritional intake, we began, as explained in our report of last year, a systematic experimental study of the extent to which the far-reaching nutritional effects are explainable in terms of differences in the internal chemistry of the normal body.

Our experimental program for the year now ending has given concentrated attention to calcium, while including at the same time some exploratory work toward the development of accurately quantitative methods for analogous experimentation upon riboflavin. As the calcium research approaches completion, the experimental facilities thus liberated will be devoted in part to an intensification of the work with riboflavin, and in part to a corresponding investigation of the extent to which the level of intake of vitamin A affects the body composition.

These three nutrient substances are of such different chemical and physical properties that each presents a separate research problem. Clearly these facts mean, also, that the relatively new field here entered is one of broad scope and significance.

In the studies of calcium, we have now completed the experimental work with the six diets principally used. These diets fall into two groups: those based on a mixture of one-sixth dried whole milk with five-sixths ground whole wheat; and those based on an otherwise similar

mixture in which the proportion of milk powder is increased to one-third. The other four diets are modifications of these basal rations in which calcium salts have been added to bring the total calcium content, in the first series to 0.64 and 0.80, and in the second to 0.48 and 0.64 per cent respectively. As indicated in our progress report of last year, it was found in the first series that as compared with a minimal-adequate level of intake a three- to fourfold enrichment of the calcium content of the food greatly increases the rate of normal calcification and significantly raises the plateau at which the percentage of calcium becomes stabilized in the mature body. This plateau was found to be the same whether the dietary level of calcium was 0.64 or 0.80 per cent of the dry weight of the food.

With the second series, the experimental work of which is just now being completed, we have (a) included determination of the rate and adult stabilization point of calcification with dietary intakes between the minimal-adequate and the threefold richer calcium contents previously studied, and (b) compared the calcification on two diets providing the same percentage of calcium, one of which is otherwise better balanced nutritionally in containing increased allowances of vitamin A, of riboflavin (formerly called vitamin G), and, to a lesser degree, of protein. The effects, as measured by the percentages of body calcium in the second or third generations on the respective diets, were as follows: (1) Each increase in the calcium content of the food resulted in a small increase in the percentage of calcium in the growing body. (2) Increase of dietary calcium from 0.35 to 0.64 per cent of the dry weight of the food increased the percentage of body calcium about one-ninth in the half-grown, and about one-sixteenth in the full-grown body. (3) A

given stage in the increase of calcium percentage involved in the normal development of the body was reached considerably earlier on the dietary of higher calcium content. (4) Adults on both diets containing 0.64 per cent calcium, and on the diet containing 0.80 per cent calcium, reached the same percentage of body calcium by early middle age. The data are now being prepared for publication in full with discussion of the statistical significance of the differences.

A supplementary research upon the influence of higher levels of protein intake upon growth and calcium retention is now approaching completion. Its data for percentages of body calcium promise to be very similar to those of the series above mentioned. Thus it is expected that the experimental determination of the plateau of optimal calcium content of food and resulting percentage of calcium in the body will be completed within the calendar year.

In the following year or two we hope to concentrate the facilities which our long-controlled families of laboratory animals afford upon the completion of the experiments already begun with riboflavin and with vitamin A. As calcium is retained in the body in the form of a substance only slightly soluble in any of the body's media, while riboflavin is freely soluble in water, and vitamin A in fats, the completion of comparative researches upon the zones between the merely adequate and the optimal intakes of these three substances should be of fairly far-reaching significance to the large problem of the extent to which the body's internal chemistry is amenable to voluntary control through scientific quantitative adjustment of the nutritional factors of our food.

The efficient service of those who have collaborated in this investigation, whether as research assistants or as volunteers, is gratefully acknowledged.

PALEOGRAPHY

E. A. LOWE, Institute for Advanced Study, Princeton, New Jersey. *Collection and study of paleographical material.* (For previous reports see Year Books Nos. 9-35, 37.)

The third volume of *Codices latini antiquiores* saw the light in December 1938. The four months preceding publication were devoted to seeing the text through the press and to supervising the printing of the collotype facsimiles. This volume, which deals with only half of the Italian material, comprises the manuscripts of Ancona, Assisi, Bologna, Brescia, Florence, Ivrea, Lucca, Monte Cassino, Monza, Naples, and Novara. The volume now in hand deals with the second half, comprising the manuscripts preserved in Perugia, Piacenza, Rome, Sarezzano, Trent, Vercelli, Verona, and Zara. If the chief interest of volume III may be said to lie in the conspicuous array of Codices Bobbienses referred to in the last report, the importance of volume IV is due chiefly to the magnificent series of manuscripts from the Chapter Library of Verona—manuscripts as remarkable for their antiquity as they are noteworthy for their texts. With volumes III and IV before him, the student of early Latin writing should be in a position to differentiate Italian uncial, half-uncial, and early minuscule and cursive scripts from similar types originating in centers this side of the Alps. It is with the formulation of these differences that the writer is at present concerned, and the results will be incorporated in the preface to volume IV. Work on this volume has proceeded

without interruption and the negatives needed for the facsimiles are practically all in hand. Some of the plates have already been collotyped. The letterpress is being prepared for the printer and proof should be reaching the editor within the next few months; and if untoward conditions do not intervene, the volume should see the light before the end of 1940. As usual, the officers of the Clarendon Press have been indefatigable in their assistance. The writer was able to re-examine the necessary manuscripts in Rome, Turin, Vercelli, and Verona. In the last-named library, work was enormously facilitated not only by the unusual kindness of the Librarian, Monsignor G. Turrini, who rendered his manuscript treasures accessible at all hours of day and night, Sundays as well as weekdays, but also by his willing cooperation, amounting to collaboration. Without his aid in verifying data and supplying useful negatives, the work in Verona would have been greatly prolonged. It is a pleasure to make due and grateful acknowledgment here.

At the same time with the preparation of volume IV, progress has been made with the descriptions and the bibliography of volumes dealing with the manuscripts of Switzerland, Germany, and Austria.

PALEONTOLOGY, EARLY MAN, AND HISTORICAL GEOLOGY

JOHN C. MERRIAM, President Emeritus, Carnegie Institution of Washington. *Palaontological, geological, and historical research.* (For previous reports see Year Books Nos. 20-37.)

Provision by the Trustees for continuation of relation to the Institution as President Emeritus, with funds for advancement of a research program, has made possible progress in a considerable group of projects, with the purpose either of bringing them to a stage of definite report or of so formulating the results as to attain another stage in our view of the subject.

In accepting the Presidency of the Carnegie Institution in 1920, it seemed desirable to call attention to the fact that a wide variety of researches in palaeontology, geology, early human history, and related subjects then under way might be carried forward to advantage, by reason of the value in maintaining and developing results already secured. This procedure appeared useful also because it seemed probable that an officer engaged in administration of research would have appreciation of his responsibilities strengthened by continuing touch with investigation on projects in which he might have had unusual experience. The program for research as President Emeritus involves, among other problems, consideration of certain of these projects upon which investigation has been in progress for a number of years.

Organization of the research program for the present year has included:

1. Advancement of work on projects in which it has been my good fortune to have unusual opportunity for discovery, description, and interpretation of new or exceptional materials.

2. Cooperation with individuals or groups in discovering ways through which combined effort made possible by common interests could find a road to results not otherwise easily attainable.

3. Review of particular problems or questions of scientific or of human importance concerning which clearer understanding seems possible by reason of past studies on unusual materials. If experience has opened a road to examination of significant scientific matters in ways not available to a comparable extent for other investigators, there seems reason for considering this opportunity as carrying also a responsibility.

Examination of subjects relating to completion of projects already under way has been relatively easy, although in many cases it has required new methods and new combinations of cooperating interests.

Development of broad cooperative programs for furtherance of important projects has proved an effective method of securing valuable results.

Consideration of the third group of topics, relating to philosophical and human values, has presented an extremely interesting, and I believe an important, problem concerning the contribution of experience and touching the responsibilities which rest upon one in a position to proceed to an advanced position in examination of such questions. In study of possibilities in this third field it is, of course, important to bear in mind that the wider the range of interests and the longer the period of one's experience, the

greater is the possibility of developing a program so extended and so complicated as to make difficult a simple statement of special importance. Apparently the values of perspective and experience may be almost nullified by increase in number of details and in complication of the problem. On the other hand, this situation may present exceptional opportunity for constructive work.

Fortunately, light on certain aspects of the situation relating to problems for which experience becomes important had been obtained in past years through careful discussion with Senator Elihu Root. In the course of many interviews Mr. Root touched on the problem of his own responsibilities concerning study of questions for which his personal experience might be especially useful. Mr. Root stressed the point that while he might continue to make contribution on subjects representing his own study, it was desirable to bear in mind that new students coming into the field with interest and enthusiasm might well be left to carry forward certain of these inquiries. There were, however, other matters for which his personal experience seemed to furnish data and perspective which might not be available to others. For some of these questions he would then have an exceptional opportunity and a peculiar responsibility.

Both in completion of investigations already under way and in study on further development of problems presented by past researches, the four volumes of *Published papers and addresses of John Campbell Merriam*, issued as Publication No. 500 by the Trustees of the Carnegie Institution of Washington in December 1938, have been extremely useful.

In the conduct of researches in past years the attempt has been made to relate the various problems to one another, and to consider the significance of each in terms of major scientific and

human questions arising from the materials of research. But, since commonly the objective of investigation has been the acquiring of specific or specialized knowledge in a limited field, it has not been possible in every case to see clearly in advance of completion of the work the relation between the basic facts and the generalized scheme of knowledge into which they fit. Often these relations have been found more easily through use of the assembled and reprinted reports.

Advancement of Projects under Way

Under the first group of projects, or the special researches which have been under way and are now being continued or emphasized, some have been wholly the personal work of J. C. Merriam; some have been cooperative work with associates; and others are covered by groups of cooperating investigators each with a particular independent objective but with the researches so adjusted one to another that each person profits by the contributions of the others, and the collective results further the understanding of certain problems not otherwise readily examined. Also in a number of cases special arrangement has been made for cooperation with an investigator peculiarly qualified to carry out a particular piece of work, the results of which are necessary for advancement of another research or for a group of studies.

Geology of John Day region, John P. Buwalda. In the field of investigations largely geological, but intimately related to studies touched by publications of J. C. Merriam in past years, one of the most important projects is that covered by the work of Dr. John P. Buwalda, of California Institute of Technology, on the structural and historical geology of the John Day region in eastern Oregon. This extensive research brings together an exceptionally important record of

data on the geology of regions which have become classic by reason of contributions to palaeontology and geology by E. D. Cope, Othniel Marsh, W. B. Scott, and others in the latter half of the nineteenth century. The work by Dr. Buwalda is now being brought to a conclusion, and will represent one of the most interesting and important chapters on the later geological periods as expressed in northwestern United States.

Paleozoic stratigraphy and palaeontology of Grand Canyon, Edwin D. McKee. Another geological-palaeontological research of great significance in which it has been my privilege to cooperate is that of Edwin D. McKee on Paleozoic stratigraphy and palaeontology of the Grand Canyon. In his position as naturalist of Grand Canyon National Park, Mr. McKee has had under way for a number of years certain special investigations on palaeontology of the Grand Canyon which have been extended in such manner as to connect the history of life with interpretation of the mode of formation of the deposits in which the remains are entombed. This has resulted in a study linking variation of life horizontally, or in different places at the same time, with the historical succession of deposits and the faunas illustrating significance of changes through time.

The studies of Mr. McKee, based as they are upon a succession of formations in a very exceptional expression of the earth's history, have unusual value both as regards the physical phenomena which have to do with the mode of formation and succession of deposits, and with reference to the interlocking of environmental influences as they relate to the variation and evolution of organisms. Recognizing the fact that scientific contributions may vary in importance according to timeliness, as also with relation to location of the materials examined, it is interesting to note that

Mr. McKee's work at the Grand Canyon not only furnishes unusual opportunity for research, but makes materials available at a point where they are extraordinarily useful for continuing interpretation of nature to interested visitors.

Ellensburg formation of Washington. A project of local scope, and yet of wide significance, upon which work has been under way for a number of years concerns the age of the Ellensburg formation of central Washington. It has been conducted by John P. Buwalda, Chester Stock, and John C. Merriam. Although the Ellensburg formation has close relationship to the Mascall formation of the John Day region in Oregon, it shows certain peculiarities both in geological and in palaeontological materials available. Determination of the age of these beds will have considerable importance in terms of the detailed history of the middle Tertiary formations of western United States.

New information obtained recently by Dr. Buwalda, Mr. Beck, and others has thrown considerable light on points regarding the Ellensburg which have not been clear, and an early solution of the problem, with better understanding of the meaning of the history of eastern Oregon and eastern Washington, may be expected.

Correlation paper of Great Basin region. A study designed to cover time correlation of the major formations in the Great Basin province of western United States, first carried to completion by J. C. Merriam twenty-five years ago, is now being extended by cooperation of John P. Buwalda, Chester Stock, and J. C. Merriam under the title "Correlation paper of the Great Basin region." During the period that has elapsed since the first organization of material on this subject by the senior author, much new literature has appeared, and it is now necessary not only to review recent literature, but to study again with care the

relationships of formations and faunas represented. No statement on this subject can ever be more than a report of progress, but it is planned to bring this material to publication as early as possible, in order that it may serve as an aid, or as a basis for continuing constructive study of the geological and palaeontological story in the Great Basin region.

Succession of mammal faunal zones of John Day area, Chester Stock. In connection with restudy of the classic John Day area in eastern Oregon, Dr. Chester Stock of California Institute of Technology has undertaken an examination of the succession of zones of life represented in the fossil mammal faunas of that region. Field work carried on from time to time over a considerable period has brought together collections which, taken with those obtained by a number of the principal museums of America, give a picture of major changes in the life of that region as represented in some of the most important divisions of late geological time.

Invertebrate faunas below John Day formations, E. L. Packard. In the geological formations of the John Day region, just below or earlier than those in which Dr. Stock has been conducting studies on succession of faunas, a further series of researches has been conducted by Dr. E. L. Packard of the State College of Oregon. The formations examined by Dr. Packard represent the Mesozoic and are mainly of marine origin. The life forms investigated represent the invertebrate group, as contrasted with the higher animals or vertebrates of the later section studied by Dr. Stock. The results of Dr. Packard's work collectively constitute an important chapter in the history of life within this section. No other comparable study has been made in this area, and the contribution is of much importance, both for the local section and for western North America.

History of antelope group, E. L. Furlong. Palaeontological researches devoted largely to a group of animals related to the antelopes have been carried on by E. L. Furlong, of California Institute of Technology, on the basis of materials secured in eastern Oregon, Washington, and Nevada. The results have furnished an important chapter on the evolution of a peculiar group of mammals. The careful examination of successive steps in evolution of these forms has contributed material of large importance for a general study on evolution of the higher animals.

Rancho La Brea. Great collections of fossil remains representing life of southern California found in the asphalt beds at Rancho La Brea, Los Angeles, have furnished the most spectacular known story of life in the geological period immediately preceding the present. Study of these materials through several decades has contributed much to knowledge of life of the past. There remain, however, several groups of animals well represented in these collections which still await adequate scientific description and interpretation.

As a part of the program designed to bring certain researches nearer to completion, a series of studies is now initiated, with the cooperation of Dr. Chester Stock, Mr. E. L. Furlong, and others, leading to fuller record, and also better understanding of groups which still require careful examination.

Evolution and adaptation of whales, Remington Kellogg. Having spent a considerable period on intensive study of evolution in highly specialized marine reptiles, it seemed to the writer many years ago that one of the best means for securing additional information concerning the processes of evolution would be found through examining the history of some of the higher animals which have become closely adapted to life in the ocean. With this problem in mind, considerable collections of fossil whales were

assembled at the University of California in the hope of carrying out a monographic study in this field.

The whales seemed especially important for such a study as has been suggested because they have become extraordinarily specialized and highly adapted to marine life. They have moreover a long geological history, and there is much fossil material available in good state of preservation.

In order to ensure continued effort toward realization of the proposed monograph, a special memorandum was presented to the Publication Board of the University of California suggesting that the work would be important, that it might be elaborate, and that presumably it would be expensive. Inquiry was made concerning the attitude of the Board toward publication of such a monograph, with the understanding that if presented it would of course be considered on its merits as a scientific paper. The Board looked with favor on the project, but a student in zoology and palaeontology, Mr. Remington Kellogg, became so much interested in the subject that the material was made available for his use. Within a few years Mr. Kellogg became the leading student of the history of whales in America, and one of the foremost investigators in this subject of the world.

The relation of Mr. Merriam to Dr. Kellogg has been maintained over these many years, since Dr. Kellogg was evidently doing a piece of research of great value in study of evolution of the higher animals, and was making a record of importance for all time.

In the past year the writer has continued his cooperation with Dr. Kellogg in furtherance of his work on evolution of whales, which has covered the developmental history of Recent and fossil whalebone whales. This research has involved for Dr. Kellogg the necessity of continued search for

additional collections from geological horizons not heretofore contributing adequate material for satisfactory evolutionary studies.

Viewing these researches on the whale group as a whole, there seems reason to believe that at some future stage the summing up of evidences of evolution may show that what is known concerning the evolution of the whale and its relatives is one of the most important chapters in study of the history of life.

Pithecanthropus of Java, G. H. R. von Koenigswald. One of the most interesting and important of all researches to which it has been my pleasure to have relation is that of Dr. G. H. R. von Koenigswald, of Bandoeng, Java, concerning the earliest known skeletal remains of man. Deeply desirous of opportunity to make contribution to knowledge of the famous early human type, *Pithecanthropus* of Java, Dr. von Koenigswald settled in Java with the idea of finding opportunity for work on this subject.

By one of those strange combinations of common interest which sometimes arise, Dr. von Koenigswald became related to the Carnegie Institution with support furnished by the Carnegie Corporation of New York. Although no new specimens of *Pithecanthropus* had been discovered for a generation, Dr. von Koenigswald was so fortunate as to secure much new material representing several skulls. The result is a vastly bettered picture of some of the most important characters of this earliest human. Fortunate cooperation with Dr. Franz Weidenreich, of Peiping, China, gave opportunity for comparison by von Koenigswald and Weidenreich of *Pithecanthropus* of Java with the similarly primitive *Sinanthropus* of China.

Further cooperation with Dr. von Koenigswald has been arranged, which it is hoped may lead to still other discoveries of important parts of the skele-

ton. In this cooperation the valuable advice and counsel of Dr. Weidenreich has been extremely helpful.

History of plants, R. W. Chaney. An extensive group of studies on the history of plants and their relation to their environment has been carried on by Dr. Ralph W. Chaney in the region of Oregon, Washington, Nevada, and California. These studies parallel those of the palaeontologists concerned with the history of animal life in these regions. They set forth also the relation of evolving plant associations to the environments in which they developed. These several aspects of research, including all phases of geology with study of land forms in the several periods, taken with results of investigation of life types, their distribution, and their succession in time, present a spectacular picture of earth history. This view is one which illustrates in exceptional manner both the processes of earth building and the mode of development or evolution of the life which occupied these regions.

Development of Cooperative Projects

In discussion of the second type of project considered important as President-Emeritus research, it is interesting to note that the most important group of cooperating investigators which recent study has brought together formed almost spontaneously to meet a need for assistance in archaeological work being conducted by Dr. L. S. Cressman, of the University of Oregon.

The group of investigators mentioned came together in response to opportunities for mutual aid suggested by studies on early man by Dr. L. S. Cressman, and comprising subjects ranging over many phases of geology, geography, palaeontology, archaeology, and anthropology. The investigations have in the main been set up independently, with specific objectives justifying their existence even without the cooperative rela-

tion. But it has been clear that with the connections established through a cooperative plan each person not only aids in a larger undertaking, but by reason of that arrangement increases the opportunity for his own program.

The work of Dr. Cressman in search for early stages of human occupancy of the south central Oregon region has been under way for several years, and is reported briefly in the Year Book of the Carnegie Institution for 1936-1937 and for 1937-1938.

The persons related to this cooperative project include: Dr. L. S. Cressman from the University of Oregon, concerned with the history of early man in south central Oregon; Dr. E. B. Howard from the University of Pennsylvania Museum, engaged in a wide study of the problem of early man in America; Dr. E. L. Packard and Dr. Ira S. Allison from the Department of Geological Sciences at Oregon State College; Dr. Warren D. Smith from the Department of Geology, University of Oregon; Dr. Ernst Antevs, a distinguished student of history of climate from Globe, Arizona; Dr. John P. Buwalda, geologist, California Institute of Technology; Dr. Chester Stock, palaeontologist, California Institute of Technology; Dr. Ralph W. Chaney, palaeobotanist, University of California; Daniel I. Axelrod, palaeobotanist, National Research Fellow; Dr. Howel Williams, geologist, University of California; and representatives of the National Park Service from the staff at Crater Lake National Park under superintendence of Mr. E. P. Leavitt.

The work of Dr. Cressman in south central Oregon has included important discoveries in the finding of human remains at Catlow Cave, in which there is evidence of considerable antiquity, although the stage of the earliest occurrences seems still to be a matter for discussion. In Paisley Cave human remains were found beneath a layer of

volcanic ash which Dr. Howel Williams of the University of California considers as derived from an early outpouring of volcanic ash from Mount Mazama, from the ruins of which the crater of Crater Lake was formed.

Numerous occurrences of human remains and artifacts in this region show association with geological features or with remains of extinct animals such as to suggest an age determination placing the human beings represented in a period near the beginning of the so-called Recent or the present geological stage. Evidence of antiquity is however sufficient to make these occurrences among the most interesting in America.

In company with Dr. Cressman, Dr. E. B. Howard has examined the principal localities studied in south central Oregon, and agrees regarding the exceptional value of these finds. Dr. Howard has wide acquaintance with the problems of early man in America through intensive special studies at Clovis and other exceptional localities, and through examination of the principal sites available. His view of the problem has therefore high value. Dr. Howard will visit these sites again when work is in progress during the next field season.

Relation of the work of Dr. Howel Williams to study of the finds of Dr. Cressman has exceptional significance, bringing together as it does the data from an archaeological, palaeontological sequence in the Oregon caves and the results of extraordinarily fine geological study of the history of Crater Lake and Mount Mazama, the source of its crater. Williams' intensive geological restudy of the Crater Lake area contributes one of the most interesting chapters to history of volcanology in America. His thorough examination of every phase in the history of the mountain reveals the manner and the steps by which the destruction took place. Thus it came

about that Williams was able to say that the ash overlying human remains in Paisley Cave originated from a certain stage in the outpouring of ash derived from molten materials of Mount Mazama. The possibility that interlocking evidence may give approximate dates is of great interest in study of both geological and archaeological problems.

In another direction the work of Dr. Williams bears upon interpretation of the early man story in Oregon through the possibilities of correlation of stages of glaciation on Mount Mazama with climatic stages suggested by evidence concerning ancient lakes touching some of the cave areas. The lake story fits into one concerning climate and precipitation changes which has been examined in this region by Dr. Ernst Antevs in association with Dr. Cressman. It may thus come about that correlation between glacial stages of Mount Mazama and lake stages, due to climatic changes which influenced the record of caves containing human remains, will help to formulate a chronology of exceptional historical value.

The story of the numerous lakes of eastern Oregon, both modern and ancient, expresses itself geologically in considerable measure in terms of sedimentation and erosion. To know the history of these lakes reaching back from the present into the geological periods immediately preceding this age is of great importance in working out the chronology of the region into which the human story fits. In order to secure the geological story of the lakes and of the related features, careful study of the region is being made, first as an independent area, and second as related to the geology of adjacent areas. There has been intensive examination of this problem by Dr. Packard, Dr. Allison, and Dr. Warren D. Smith.

At the request of the cooperating group Dr. Allison has devoted himself

in recent months to a study of the south central Oregon region with a view to interpreting it in some measure in terms of what is known of areas to the north and to the west. This contribution is proving of great importance, and the careful work of Dr. Allison will give some of the largest values in the whole range of the cooperative program. The careful discussion of these researches with Dr. Packard and Dr. Warren D. Smith will afford an exceptionally fine view of this situation.

Dr. John P. Buwalda, who has had extensive experience in geological studies in eastern Oregon, is also acquainting himself with the situation in south central Oregon with a view to bringing to bear upon this particular problem the information secured in research in north central Oregon and Washington.

Time correlation of the various elements involved in this interlocking program may prove to be most easily accomplished by use of the changing succession of life forms furnished by palaeontological remains of the higher animals secured from caves, lake deposits, terraces, ash deposits, and other types of occurrence. Fortunately fossil remains are not rare in the region and are of frequent occurrence in some of these areas. Fossils are sufficiently common in the cave deposits to furnish an important record running parallel with that of remains of man.

Dr. Chester Stock, who has had long experience in research on the later faunas of eastern Oregon, is devoting himself to examination of the collections secured in the cave and lake regions. He will also make comparison of these faunas with those from adjacent regions in which the palaeontological story has been worked out in relation to known geological sections.

Effort is being made also by Dr. Ralph W. Chaney and Mr. Axelrod to secure such data from fossil remains of

plants in this region as will aid both in determination of geological age and in the interpretation of climatic conditions.

The possibilities of aid to those engaged in the interlocking series of studies on the south central Oregon region have seemed so important to the investigators concerned that an informal organization has been set up, with machinery which will make it possible for all to know what is being done in each research. In this way the individual contributes to the group and the group assists each cooperator. The special studies may all be published independently, or combinations may be arranged for interpretation of particular situations or questions. The result of these cumulative researches is certain to help materially in the supremely interesting work on the history of man in this region.

Looking forward to a time when the principal investigations shall attain their major objectives, it is hoped to see the results brought together in an easily intelligible statement to inform the interested public.

Among the avenues through which the readily interpretable results may flow will be the organization designed to aid visitors to Crater Lake National Park in appreciation of that region. The State University of Oregon, the State College of Oregon, and the educational institutions of California represented in this work furnish other important channels through which interpretations will be disseminated.

Basic Questions That Have Arisen from Research

Certain groups of major scientific, philosophical, and practical questions long in my mind have raised themselves in this review of past work and the planning of its natural fruition. Perhaps something is accomplished in the

attempt to state or suggest these matters; which may be done as follows:

1. Discussion of evidence from the record of the rocks indicating variation of life geographically, or in space, in accommodation to changes in the environment to which life becomes in a measure adapted. Study of relations in ecological adjustment in past ages as an influence advancing evolution.

2. Evidence from geology and palaeontology indicating variation of life through time, or evolution of life forms, perhaps caused in part by adjustment to changing environments and partly due to certain basic laws or factors of evolution with which as yet we are only imperfectly acquainted.

3. Consideration of indications that the archaeological, palaeontological, and geological records show changes, adjustments, evolution in the longer story of man, due to influences or laws similar to and comparable to factors apparently responsible for evolution in other living forms of past ages.

4. Consideration of localities and materials which appear exceptionally favorable for realistic illustration of geological and palaeontological factors which have been concerned in the development of life and of man in past ages. Studies have been carried out for this purpose in such regions as the Grand Canyon of the Colorado, Crater Lake of Oregon, the Oregon State Park System, the Point Lobos State Park of California, and the Redwood region of California. Many published statements concerning these studies are of record.

5. Examination of evidence suggesting that contributions of science may come to have large value in formulation of a philosophy with wide-reaching implications for human life. Consideration of the possibility that such a philosophy might furnish basic principles of value in a re-statement of religion or of ethics which would be acceptable to a large percentage

of thinking people. Re-examination of the idea that the greatest contribution of science may concern its influence in the determining of our attitudes of mind and our aspirations.

Recent studies relating to application of science in human affairs have shown that, along with other uses, we must consider the influence of scientific materials and methods upon various phases of human interest and ideals or objectives in life. Attainment of an understanding of the problems presented in this field requires wide vision and exceptionally clear perspective. It constitutes one of the most interesting and important questions of this age.

6. Intensive study of contributions from science toward a type of interpretation of nature which might have larger human value than has thus far been found commonly in love of nature or in appreciation of nature as generally visualized.

As study on the meaning of science advances, it becomes increasingly clear that some of the most important values arise from recognition of the necessity for consistent building upon tested realities in all aspects of thought. The things to which we give highest value ultimately are those which are checked by intensive and extensive investigation, or which are shown to stand the test under long experience. Where science through investigations of the most rigorous type produces results which we feel under the necessity of accepting, a foundation is laid having value of an exceptional order for what may be built upon it.

My own field of special study, on history of life as related to history of the earth or to evolution, presents certain great truths which seem to have meaning in relation to human values and affairs. There is reason for continuing effort to discover what may be obtained by research or intensive inquiry in this

field, with use of a perspective involving man's true relation to nature, both with respect to his origin and to his continued growth or development in the natural world.

The securing of details relating to research in the fields of palaeontology, geology, geography, archaeology, history, and other phases of science presents a challenge of such a nature that it may absorb all of the interest and energy of a vigorous human being. The results of such work have their application in a vast range of things academic and practical. But if the largest possible contribution is to be made, somewhere in the program of such research there must be included the use of all the penetrating vision and synthetic organization that intelligence can bring to bear; otherwise we shall fail to secure the largest values both in the academic-philosophic sense and in practical human application.

In the course of many decades devoted to research interpretation, and in some measure to educational and social application, it has been my continuing practice to program work in such manner as to focus attention in each prob-

lem so as to bring out principal relationships to other knowledge, and to develop what would seem to be the more fundamental truths. Accumulated experience and widening knowledge of the subjects investigated have stimulated an interest in what appear to be major values as they relate to human use and well-being, and have seemed to demand that perspective be utilized so far as possible.

It has, therefore, seemed unavoidable that, as one responsibility in connection with President-Emeritus research, so much of the time available be devoted to examination of these problems as appears to offer possibility for fruitful organization and interpretation of new materials arising from investigation of great realities in nature. Especially is this desirable in the case of matters that contribute in any way to the development of connections between use of the natural sciences and of those phases of intellectual activity relating to social or other distinctly human problems, such as are represented in history, sociology, education, anthropology, government, philosophy, religion, art, and in appreciation of the world environment in which we find ourselves.

RESEARCH ASSOCIATES

STUDIES ON VERTEBRATE PALEONTOLOGY IN THE PACIFIC COAST AREA

CHESTER STOCK

Development of vertebrate paleontological research has proceeded along three principal lines and includes initiation of field work and study in the paleontology of the Mesozoic of California, not heretofore attempted.

Quaternary studies. These include continuation of research on the valuable materials from the asphalt deposits of California, particularly those of Rancho La Brea. A monographic study of the Pleistocene Camelidae is progressing toward completion, as are also shorter

contributions on the Canidae. A paper entitled "Life on the San Joaquin Plain during the Ice Age" has been accepted for publication. The Quaternary studies emphasize also the early history of man in America, and a review of prehistoric archaeology has been completed for the Semicentennial Anniversary volume, featuring a digest of the progress of the geological sciences during the past fifty years, of the Geological Society of America.

Tertiary studies. Several important problems relating to the geology and paleontology of the Tertiary of western North America have been investigated and reports completed.

Dr. R. W. Wilson has now completed his studies of the significant early Tertiary rodent faunas obtained in the Sespe and Poway formations of California. These studies not only bring to light an assemblage of mammals previously unknown or little understood for this section of North America, but furnish also important evolutionary links in the history of the rodent group as well as a basis of more accurate correlation and age determination of the faunas involved. These papers mark one of the important steps in the advance of our knowledge of the history of rodents made in recent years.

Additional fossil mammals occurring in Eocene faunas of California have been studied. A paper by Chester Stock dealing with the aquatic rhinoceroses and entitled "Eocene amynodonts from southern California" was published in the *Proceedings of the National Academy of Sciences*. Likewise a statement by Chester Stock concerning the interesting group of tarsiid primates and entitled "Our earliest relatives in California" appeared in the September issue of *Westways*.

Richard H. Jahns has completed a study of the stratigraphy and vertebrate paleontology of the Mint Canyon series of southern California, and the results are being submitted to the Carnegie Institution for publication. This comprises a detailed and comprehensive investigation of a critical region in the Tertiary record of the Pacific coast and for the first time establishes clearly the relation of two fossil vertebrate assemblages, the Mint Canyon and the Tick Canyon particularly, with regard to Miocene marine records on the Pacific coast. A second important contribution to Tertiary stratigraphy and vertebrate paleontology on the Pacific coast, wherein are established the relations of a land-laid accumulation and a mammalian fauna intercalated in a section made up of marine deposits, has been completed by

J. F. Dougherty. This report, entitled "A new Miocene mammalian fauna from Caliente Mountain, California," is being submitted to the Institution for publication.

Paul C. Henshaw has undertaken the study of a large and significant mammalian fauna from upper Miocene deposits near Tonopah, Nevada. The assemblage promises to shed considerable light on the development of vertebrate life in the Great Basin during the Miocene and will aid considerably in the interpretation and correlation of this stage in Tertiary history.

Mesozoic studies. A promising and important new field of investigation was undertaken this year in the study of fossil reptile occurrences in the Cretaceous deposits of the Coast Ranges of California. Plesiosaurs, mosasaurs, and hadrosaurian dinosaurs have been uncovered in the Moreno formation of western Fresno County, and a vigorous program of field investigation has been instituted. For the first time it is possible to record these reptiles on the basis of rather well-preserved specimens and from a province of North America which until a few years ago gave no evidence of the presence of these forms. Discovery of different kinds of fossil reptiles sheds most welcome light on environmental conditions along the Pacific Coast during later stages of the last period of the great Age of Reptiles, and permits a correlation of the fossil-bearing deposits with Cretaceous accumulations elsewhere on evidence other than that furnished by marine invertebrates. The dinosaur remains are now being studied and a preliminary statement will soon be ready for publication.

STUDIES ON THE HISTORY AND EVOLUTION OF WHALES

REMINGTON KELLOGG

Most of the past year has been devoted to a continuation of the investigation of

the developmental history of recent and fossil whalebone whales. Besides the factual data that ordinarily are assembled in the course of such comparative studies, the inquiry has brought to light many puzzling structural peculiarities in the skull and skeleton of the cetotheres, the predecessors of living whalebone whales. The origin and sequence in geologic time of these fundamental structural changes have a direct bearing on the morphological and physiological adjustments that permit a mammal to cope successfully with the conditions imposed by habitual life in the water. This has emphasized the necessity of continued search for additional material from geological horizons older and younger than the Miocene Calvert formation. Consequently, a number of promising localities where such material may possibly be obtained have been visited in addition to the usual field work in the Calvert formation.

During the past year, several accounts were published in the press of the finding of a supposed "zeuglodon," one of the early Tertiary precursors of the Cetacea, on the farm of Barbee Spindle at Hustle, Essex County, Virginia. Arrangements were made with Mr. Spindle to visit the site. On arrival it was found that the skull and nearly complete skeleton of a cetothere had been excavated in the St. Marys formation. Since Mr. Spindle has found it profitable to exhibit the skeleton as it now lies in the ravine bottom, it is not likely that this interesting specimen will pass into the possession of some museum until the novelty has worn off.

Having been informed by Mr. George C. Barclay of Newport News, Virginia, that a cetothere skeleton had been uncovered in the Yorktown formation on the west bank of the York River about 5½ miles east of Williamsburg, the writer visited the site in company with Messrs.

Barclay and C. W. Gilmore during May 1939. Although this skeleton was found to have been destroyed by tidal action, it was possible to assemble sufficient scattered fragments of the skull to determine that it represented a large form hitherto unknown. Following this, a visit was made to Conetoe Creek, southeast of Tarboro, North Carolina, where scattered remains of cetotheres had been uncovered in the Yorktown formation by a dredge. Opportunity was afforded on the return trip to study the cetothere material in the collections of the State Museum at Raleigh and of Duke University at Durham, North Carolina.

One of the old marl pits on the Wickham estate west of the Pamunkey River near Hanover, Virginia, was visited in an effort to locate the source from which E. D. Cope in 1895 had obtained a collection which included among others the type of *Mesocetus siphunculus*. Several marl pits located near the Pamunkey River between Doswell and the South Anna River were worked about that time, and in the absence of specific locality data, it is not likely that the precise pit can be determined. The material collected indicates that Cope's collection came from the basal Calvert formation.

The résumé of our present knowledge of the adaptation of structure to function in whales which was published in *Cooperation in research* (Carnegie Institution of Washington Publication No. 501) focused attention on the lack of precise information regarding the habits of many kinds of living cetaceans. It seemed desirable to prepare for publication a general account of what was actually known regarding the life history and habits of some 45 whalebone whales and porpoises.

Mr. Sidney Prentice has been employed at different times to make illustrations of some of the cetotheres.

STUDIES ON THE HISTORY OF GRAND
CANYON PALEOZOIC FORMATIONS

EDWIN D. MCKEE

Investigation of the stratigraphic relationships between Paleozoic formations in various portions of the Grand Canyon of Arizona has been continued during the past year. One of the principal objectives in these studies has been the determination of the nature of lateral transitions or changes in both fauna and sediment that accompany each vertical change in the highly variable lithology of the Canyon walls.

Two principal methods of approach have been employed. One is a continuation of the measuring of detailed sections, selected at strategic points, to demonstrate relations between sedimentary units and fossil horizons. The other is a statistical study of the dip and strike in cross-laminated beds. From this investigation many data have been obtained relative to the agents of deposition, the directions of transportation among sediments, and other environmental factors.

In the Cambrian formations, detailed sections measured in Meriwitica Canyon and in Grand Wash Cliffs help substantiate other evidence indicating that much of the green shale of eastern Grand Canyon is replaced westward by dense mottled limestone and that the "snuff-colored dolomites" represent an intermediate stage. Other new data on the Cambrian problem come from Grand Wash Cliffs, where the known upper limit of the Lower Cambrian and the lower limit of the Middle Cambrian have been extended, through the discovery of new fossil horizons, until separated by only 55 feet of sediments. No evidence of unconformity has been detected in this interval.

Statistical studies of cross-lamination in the Tapeats sandstone have demonstrated that the Cambrian sands of this area had a regional direction of move-

ment ranging between west and southwest. It is believed that this represents the direction of along-shore currents, therefore it does not necessarily indicate a direction opposite that of source. In other statistical studies, made in areas where Pre-Cambrian monadnocks had formed islands in the early Cambrian seas, evidence indicates that these hills had little or no influence on the direction of movement among the sediments that were deposited at their bases.

In the Devonian Temple Butte formation further data were obtained to illustrate the remarkably rapid thickening of the limestones from east to west in Grand Canyon. The section at Meriwitica Canyon was found to be 743 feet thick; at Grand Wash Cliffs, 26 miles farther northwest, 1272 feet. On the basis of lithologic evidence there is good reason to consider this formation equivalent, in part at least, to the Jerome formation which is found along the southern borders of the Colorado Plateau. Several unusual and distinctive types of limestone are common to both units.

Throughout much of eastern Grand Canyon thick limestone beds which are above the well-known lavender pockets of Devonian age, and which have previously been included in the Redwall formation, are believed to belong to the Devonian sequence. Evidence of marked unconformity above and not below them, and lithologic similarity to certain definitely Devonian beds farther west, indicate this relationship. Further tracing of beds and attempts to secure paleontological evidence, however, will be necessary in order satisfactorily to work out the Devonian history of Grand Canyon.

In the Supai-Hermit red-bed sequence of Permian and Pennsylvanian (?) age, a conglomerate bed below the base of the highest or Esplanade cliff has been located in many sections throughout the Plateau region. Although it is formed of limestone and siltstone pebbles ob-

viously derived from the underlying beds, its importance as a major break in the red-bed sequence is indicated by (1) its persistence throughout the area, (2) the distinctive types of cross-lamination, and different average directions of movement indicated by lamination surfaces above and below it, and (3) the westward transition of the underlying beds into limestones, while those above remain as red beds throughout Grand Canyon and beyond.

From an analysis of many measured sections of the Supai-Hermit formations, illustrating lithologic transitions from east to west through the Grand Canyon, it appears fairly certain that the Callville formation of western Arizona and the Bird Spring of Nevada are equivalent to that portion of the Grand Canyon Supai which is below the conglomerate. The "Supai" formation of Nevada and western Arizona, on the other hand, is equivalent to the combined Hermit shale and Grand Canyon Supai above the conglomerate. Furthermore, cross-lamination studies in the upper Supai unit show an average regional direction of movement of about S. 55° E., while those made below indicate a direction considerably more toward the south.

EARLY MAN AND CULTURE IN THE
NORTHERN GREAT BASIN REGION
OF SOUTH CENTRAL OREGON

L. S. CRESSMAN

This report covers the laboratory work and preparation of manuscript since the end of the 1938 field season, and the work of the 1939 field season. A report on the 1938 field season appeared in Year Book No. 37 (1937-1938).

Studies of the problem of the skeletal material uncovered in the gravel of Catlow Cave No. 1 have continued. The stratum bearing the skeleton has been definitely proved to be of lacustrine ori-

gin, that is, it was washed by lake water in the cave, as is shown by the presence of diatoms in the specimens from above and below the skeleton. The species has been identified by Mr. Paul S. Conger, Research Associate of the Carnegie Institution, as *Melosira arenaria* Moore, a species characteristic of freshwater lakes. Further examination of the materials shows a marked degree of weathering and some rounding by wave action. The general import of all the information, from all different angles, that can be brought to bear on this problem seems to the writer entirely convincing evidence that the body was naturally deposited at the time when, under ordinary conditions, water was in this cave with slight wave action which would, of course, be increased in time of storm. It is the writer's opinion that the skeleton represents a deposit from the early Recent period. The actual final proof of the natural deposition, beyond any shadow of doubt, can never be given.

From this cave, in the materials overlying the skeleton-bearing stratum, the external cuneiform of a Pleistocene horse (identified by Dr. Chester Stock) was recovered last summer. This was in the annual exhibition of the Carnegie Institution at Washington last fall. This further establishes the antiquity of the skeletal material, although the *Equus* bone was not immediately over the skeleton but perhaps 10 feet farther down the trench from it.

Dr. Howel Williams, of the Department of Geology of the University of California, has definitely identified the pumice from Paisley Five Mile Point Cave as coming from Crater Lake. This is also true of the knives from the Deschutes terrace which we have called the Wikiup knives. This winter a third knife was recovered from the stratum over the pumice on the other side of the Deschutes River from the first locality and perhaps $\frac{1}{4}$ mile farther up the river.

The pumice overlying this artifact was also identified by Dr. Williams as coming from the Crater Lake source. The pumice from the Fort Rock Cave is identified as coming from the Newberry Crater and is probably more recent than that from Crater Lake. In both cases, however, occupation levels lie under the pumice and over it.

Field work from June 13 to July 21, 1939. A party of nine including the Director carried out further investigations of the caves in the Summer Lake region near Paisley, two of which had been partially excavated in the 1938 season. The party was broken up into a number of details. One which consisted of three men was sent to Warner Valley, some 75 miles to the east, to excavate some caves in that region. This party spent five days in these caves and found them to contain practically nothing but some matting.

Another party carried out exploration looking for further caves in the Summer Lake region, but were unsuccessful in finding anything beyond those known in 1938. This detail, however, did find a hitherto unreported invertebrate fossil locality, which may eventually prove useful in working out the chronology of the lake. Some beds promising for vertebrate fossils were also located but could not be explored at that time.

A third detail was clearing up the caves worked in in 1938, preparing them for complete excavation. One of these was the one in which Crater Lake pumice was found overlying an occupation level, and the adjacent cave from which atlatl shaft butts were taken but about the stratification of which no certain conclusion could be reached because of unsatisfactory working conditions and the short time available.

The party completed the excavation of the Five Mile Point Cave, here called No. 1. It was the cave in which clear

stratigraphic sequence showing the Crater Lake pumice had been found in 1938. Under the pumice were found a number of points and scrapers of a Folsomoid type. No true Folsom point, however, was found. Some bits of basketry were also found. There were also some pieces of basketry and points the location of which was not certain because of the activity of pack rats in the cave.

In the meantime Cave No. 2 was being excavated to determine whether this presented the same sequence of occupation and pumice as Cave No. 1. With working conditions somewhat better this year than last, it was possible to complete the excavation of this cave and verify the same sequence as in Cave No. 1.

While the excavation of these two caves was being completed, a detail was working on the test pit in Cave No. 3, about 25 meters farther along the rim. The test pit extended through occupation material, then a stratum of pumice, apparently from the same source as that in the other caves, and sterile material to about 20 cm. above the gravel, where partially mineralized bones and an obsidian reject were found. These bones continued to the gravel and the sand lying on the gravel. They extended out from the wall of the cave some distance to the front, but were mixed and presented the appearance of having been thrown into a pile. Fragments of long bones were broken evidently for the marrow, and black stains in the deposit were apparently ash. This last part, however, has not been verified, but will be at the earliest opportunity if the specimens secured make chemical analysis possible. With the bones just above the sand was found a part of a crude obsidian knife, so that the association of man with the bones is beyond question. The bones were sent to Dr. Merriam at Berkeley, who turned them over to Dr. Chester Stock of the California Institute of Tech-

nology for identification. The pertinent part of Dr. Stock's letter follows:

The bird bones included in the collection represent pintail, teal, duck, hawk, and sage hen. The mammals represent bison, mountain sheep, camel (probably *Camelops*), horse, a large dog (wolf), a fox (perhaps red fox), and probably bear. Among these mammals are two genera, namely horse and camel, that we generally regard as more characteristic of the Pleistocene than of the Recent epoch. Some of the remaining forms do not range in the region where the cave is located at the present time. The avifauna suggests the presence of water.

We apparently have, then, in Paisley Five Mile Point Cave No. 3, an association of man with the extinct fauna of the late Pleistocene or early Recent, and this association of remains lies on the gravels of the top terrace of the Pleistocene lake. This corresponds to the association of the human remains and the *Equus* bone in Catlow Cave No. 1, or it perhaps may be better put in this way: it fits into the pattern of the relation of human and *Equus* remains in Catlow Cave No. 1, where the *Equus* bone was found at a somewhat higher level than the skeletal remains. A further contribution has thus been made to the history of early man in the New World.

July 26, the party moved to McDermitt, Nevada (on the Oregon-Nevada line) for reconnaissance work on the old Lake Lahontan bed in Oregon. Two weeks' work in the Lahontan basin in Oregon showed the complete lack of any occupied cave, either historic or prehistoric. The same may be said of the valley floor representing the old lake bed and the canyons of the old rivers draining into it. The following explanation is purely tentative: After the early period of very deep water which formed the general structure of the lake basin, a period of aridity occurred and uplift took place in the northern part of the area. This lake was of early Pleistocene or

an even earlier period. As a result of the uplift, when the high water of the late Pleistocene or early Recent cut the terraces, which are clearly to be seen in Nevada some 40 miles to the south beyond the strait through which the water passed into Oregon, the water in the Oregon area was not deep enough to cut any pronounced terraces. Because of the older rocks in this region, the great mass of material loosened by erosion has obliterated much of the evidence of early lake conditions. A second point that might be made here is that the passage from north to south, assuming that it might have been that way, was much more difficult in this region than in the region to the west. The country in the west is less rugged, water is more available, and river systems provide means of movement north and south which are not found in this region to a comparable degree. At any rate, the Lahontan area in Oregon need not be investigated any further.

A final week was spent investigating caves on the east side of the southern part of Alvord Valley just across Steens Mountain from Catlow Valley. The east side of the valley is lacking in springs and consequently human habitation would have to depend upon lake water. Examination of approximately ten caves showed two in which occupation occurred on the gravels. In one of these the overlying material was thin and consequently no age could be attached to it. It is interesting, however, that cactus was found in the camp débris of this cave, and cactus is apparently foreign to this environment at present.

In one of the series of caves which the writer tested with two assistants at a depth of about 4 to 4½ feet, fire lenses were found on the gravel of the top terrace level overlying probable aeolian deposit, which was in turn overlain by decomposed roof material, and this was, in turn, covered by some 15 to 20 cm. of

dry cave débris. Again we have evidence of man's association with the exposed gravels of the upper terrace of these Pleistocene or early Recent lakes. In the case of this lake, the inhabitants must have had to move out as soon as the lake began to dry up and its alkaline character developed. In this particular area there is a hot borax lake which must have affected the quality of the water even at that time. This evidence fits the Alvord lake into the pattern of that of Catlow Valley and Summer Lakes to the west.

It would be desirable to excavate the Paisley Five Mile Point Cave No. 3 completely in view of the assemblage of extinct faunal and human remains. The south part of Alvord Valley needs no further examination, although it is possible that a reconnaissance in the area north of the Alvord Desert, the northern boundary of the area in which this summer's party was working, might be productive of important results.

Three papers have been prepared for publication and will be published in the University of Oregon Monographs, *Studies in Anthropology*, probably in the late summer or early fall. They are as follows: "Early man and culture in the Great Basin: preliminary report," by L. S. Cressman; "Atlatls from south central Oregon," by L. S. Cressman and Alex D. Krieger; "Stratified sites in south central Oregon," by L. S. Cressman and Howel Williams. A paper entitled "Early man in the northern part of the Great Basin of south central Oregon" is to be presented before the Pacific Science Congress at Stanford, August 7, 1939.

Work has progressed on the preparation of a general monograph describing our work, and it is planned to have it ready for publication by the end of 1939. The results of this summer's work will be incorporated in it. It is a detailed report, and an effort will be made to indicate the relation of this area of

south central Oregon to the surrounding regions. This work is well under way, with all the general information and descriptive material prepared, and description of most of the artifacts worked out. Practically all the drafting and preparation of drawings and photographic work for plates has been completed.

STUDIES ON THE PAST CLIMATE IN RELATION TO MAN IN THE SOUTHWEST

ERNST ANTEVS

One of the features employed in the study of the Quaternary climatic history of the Southwest are river terraces. The San Juan River, and its tributaries, which rise in the high San Juan Mountains of southwestern Colorado, have beautiful terraces which have been studied between Blanco and Shiprock in New Mexico. The terraces consist of a shelf cut in soft sandstone and shale, covered by a bed, 10 to 20 feet thick, of gravel consisting of hard, strong, waterworn, and polished pebbles and cobbles. The steep terrace steps are 25 to 100 feet high, and the treads, or the preserved terrace remnants, are from 100 feet to a mile wide. The terraces thus form gigantic steps leading to a table—the topmost terrace, which has been isolated by erosion, because its gravel is more resistant than the soft rocks against which it was deposited. Of the several terraces, the most persistent ones are those which at the distal, upper edge stand about 25, 75, 170, 230, and 270 feet above the modern river bed.

The formation of the principal terraces was without doubt caused by variations of the streams and of their load, and of the rate of the runoff, in turn caused by climatic changes. The cobbly gravel may have been transported from the San Juan Mountains during the melting of the Pleistocene glaciers that occupied their slopes and valleys. This is probable, be-

cause the river then had its greatest capacity, being fed both by the current precipitation and by glacial meltwater, and because, in the released glacial *débris*, it had easier access to loose, unprotected material than at any other time and consequently was overloaded for the slackened flow in the gently sloping valleys. Each persistent gravel bed may therefore record a Pleistocene deglaciation. The subsequent erosion through the aggraded valley floor and into the underlying soft bedrock may have taken place during the long Inter-glacials, when the available *débris* in the mountains was less and the water consequently arrived without a hampering load in the plateau valleys. Although the field observations have not been studied, it appears that the gravel veneer of the 75-foot terrace was deposited during the last deglaciation, some 20,000 to 10,000 years ago.

During the Postglacial, the river has cut into its aggraded late-glacial bed and removed most of it. A silt-filled channel near Shiprock shows that the erosion proceeded to below the modern river level. Later, silt was deposited at levels standing some 30 feet above the present river bed. Finally, the river was lowered to its present position.

Some 50 years ago a denser vegetation than exists at present extended to the water's edge. The river flow was rather steady. The water was clear except during floods. In 1911 an exceptional flood tore out the river banks and the protecting shrubs and trees and deepened and widened the channel. Erosion has occurred ever since in spite of the fact that most of the water is taken out for irrigation. The water is very muddy because of a deficient vegetation cover on the watersheds. The modern conditions suggest that also in the past the river in this section has eroded mainly during floods coming during dry ages with comparatively scanty vegetation

cover and therefore excessively rapid runoff. If so, the deep postglacial erosion is confirmatory evidence of the warm and dry Middle Postglacial (Post-pluvial); and the subsequently raised river bed is evidence of moister conditions with a denser vegetation cover on the tributaries and consequently checked runoff and diminished floods. Buried ruins and potsherds show that the river was at most a few feet higher than today about A.D. 1000, but some 20 feet higher about 1200 or somewhat later.

The sites of the Black's Fork stone culture¹ in the southwestern corner of Wyoming were visited under the guidance of Professor Renaud. The sites are workshops, not camps, and occur on river terraces which supply the only rocks in the region suitable for implements. The material consists of hard, waterworn pebbles and cobbles which form a veneer on the river terraces and which doubtless have been brought down from the Uinta Mountains, 50 to 75 miles to the south. As in the case of the San Juan, the Black's Fork may have had sufficient transporting power to do this only during the Pleistocene deglaciations. Consequently the lowest terrace gravel may date from the last deglaciation, some 20,000 to 10,000 years ago. Thus also, the lowest occurrence of the implements in situ above the river dates them to a certain extent; and artifacts if in situ on the lowest terrace are less than 10,000 years old. While most of the artifacts occur on the higher terraces, some do occur on the lowest, but these can have been washed down. However, extensive collecting, terrace by terrace, should date the culture in relation to the deglaciations.

In collaboration with the Gila Pueblo Archaeological Institution, of Globe, Arizona, field studies were continued on the

¹E. B. Renaud, *The Black's Fork culture of southwest Wyoming*. Dept. of Anthropology, Univ. of Denver (1938).

Cochise stone culture in Whitewater Creek near Douglas, Arizona. The Cochise culture is the oldest of several cultures which form a fairly continuous record of aboriginal man in southeastern Arizona from pluvial times to the present, or for more than 10,000 years. This is possibly the longest known sequence of cultures in the entire Americas. The occurrence of the implements and camp sites in valley deposits calls for close collaboration between archaeology and geology to permit determination of sequence and age. The numerous long exposures in the walls of the arroyo present beds deposited in lakelets, cienegas, permanent stream, and arroyos. The beds are sometimes separated by erosion stages. Beds, fossils, and erosions supply data on the climatic history. While Mr. E. B. Sayles excavated pluvial and postpluvial sites, rich in artifacts and mammal bones, the writer devoted most of his time to the study of new exposures, to correlation of beds, and to mapping of some 13 miles of the arroyo.

The writer also continued his general studies of the deposits, erosions, and buried tools and potsherds exposed by the modern arroyo cutting, with a view to deciphering, appraising, and dating the climatic variations in the Southwest during the past few thousand years. Sherds, collected for the purpose of dating young beds or recent events, have been identified by Dr. Harold S. Colton of the Museum of Northern Arizona in Flagstaff, Professor Emil W. Haury of the University of Arizona, and Mr. E. B. Sayles of Gila Pueblo.

ANTHROPOLOGICAL AND HISTORICAL STUDIES RELATING TO THE EARLIEST EVIDENCE OF MAN

G. H. R. VON KOENIGSWALD

The Trinil and Djetis layers of Solo, Central Java, have fortunately yielded a further increase in fossil remains, in

most cases additional material of species already known. The most important find, made early this year, is a heavy male *Pithecanthropus* skull, of which we found first the nearly complete upper jaw and later a part of the back of the cranium.

The upper jaw, lacking only the last two molars of the left side, shows also the alveoli of the incisors, of which one has been found isolated. The teeth, M_3-C arranged in one straight line, are of exceptional size (M_3-C 67 mm.). The canines are large but very much worn, with a mesial facette caused by a large lower canine. In front of the canines is a distinct diastema. The isolated lateral incisor is shovel-shaped. The prognathism of the jaw is less pronounced than we should expect in such a primitive human being, and is often surpassed by modern Mongols.

The back of the head is broken, evidently smashed by a blow with a big stone implement or a club when the bone was still fresh, causing the death of this individual. The occipital bone shows a marked upper boundary of the occipital torus and a well-developed crista occipitalis externa, and shows by this characteristic a close resemblance to the same part in the male *Sinanthropus* skull no. III, locus L.

Dr. von Koenigswald, supported by the Government of the Netherlands East Indies and the Carnegie Institution, was able to stay from February till May in Peking, in order to compare, in collaboration with Professor Dr. F. W. Weidenreich, the new *Pithecanthropus* finds with the original *Sinanthropus* material. Such a comparison was absolutely necessary, since Davidson Black, the discoverer of *Sinanthropus*, in the description of the first skull of the Peking Man had already pointed out its close resemblance to *Pithecanthropus*—later confirmed by Weidenreich; while on the other side Dubois, who discovered the first *Pithecanthropus*, denies any relation between

the two, suggesting that his *Pithecanthropus* is a "gigantic species allied to the gibbons."

As a result of their joint studies in Peking, Dr. Weidenreich and Dr. von Koenigswald believe that they are justified in referring the following finds to *Pithecanthropus*:

- "1. Skull cap of Trinil (Dubois, 1891)—*Pithecanthropus* skull I
2. Mandible of Kedung Brubus (Dubois, 1890)—*Pithecanthropus* mandible A
3. Juvenile skull of "*Homo modjokertensis*" (Geol. Survey, 1936)
4. Mandible of Sangiran (von Koenigswald, 1936)—*Pithecanthropus* mandible B
5. Skull of Sangiran (von Koenigswald, 1937)—*Pithecanthropus* skull II
6. Skull fragment of Sangiran, juvenile (von Koenigswald, 1938)—*Pithecanthropus* skull III
7. (a) Maxilla of Sangiran (von Koenigswald, 1939) and (b) skull fragment of Sangiran, adult (von Koenigswald, 1939)—*Pithecanthropus* skull IV

"The above enumeration excludes the femur from Trinil as well as the subsequently recovered femora considered by Dubois as also belonging to *Pithecanthropus*, because of their rather doubtful affinity. The same is true of the three teeth from Trinil. Of the skulls, I and II undoubtedly represent crania of individuals of advanced age, since the sutures are completely fused in skull II and almost so in skull I. *Pithecanthropus* III, on the other hand, the sutures of which are widely open, represents a rather young individual whose age cannot be estimated with any degree of certainty. The skull of *Homo modjokertensis* belongs to a child of approximately eighteen months for which we have no fossil comparative material. The two lower jaws and the upper jaw belong to adults.

"The Sangiran skull (*Pithecanthropus* skull II; see fig. 1) and the Trinil skull resemble each other as closely as two eggs. The skull is only slightly smaller than the first one—its capacity being 835

cc. as compared with 914 cc. of the Trinil skull—but its parietal and occipital parts are relatively broader so that the postorbital constriction is more pronounced here."

"This skull, preserved up to the basal region, conforms in every respect, such as size, shape, and details, to Dubois' Trinil specimen. Dubois, however, opposed the reference of this skull to *Pithecanthropus*, on the ground that the likeness in form was due to artificial adaptation of the fragments on the part of the discoverer. Such an accusation, however, is without justification. The details of the interior as well as exterior surfaces of the skull as also the skiagrams, delineating the otherwise indistinct sutures and breakage lines, fail to show even the slightest trace of an irregularity or deformation, which would be unavoidable if the fragments had been artificially adapted."

"The Sangiran fragment (*Pithecanthropus* skull III) is, in its preserved part, not as flat as the other two mentioned first but otherwise resembles them in every detail. It bears a distinctly pronounced crista sagittalis over which the sagittal suture courses, defined on each side by a depression as in *Pithecanthropus* I and II.

"Of the *Sinanthropus* cranial material, skulls E and II of locus L are most suitable for a comparison, having capacities of approximately 915 and 1015 cc., respectively. These skulls are slightly larger than the *Pithecanthropus* skulls, especially when compared with skull II, but they are the same in general form and particularly in height. The auricular height-length index in *Sinanthropus* is even slightly smaller.

"The main differences as far as the skull cap is concerned are that, on the one hand, in *Pithecanthropus* the supraorbital tori pass directly over to the extraordinarily flattened forehead, whereas in *Sinanthropus* the supraorbital ridges

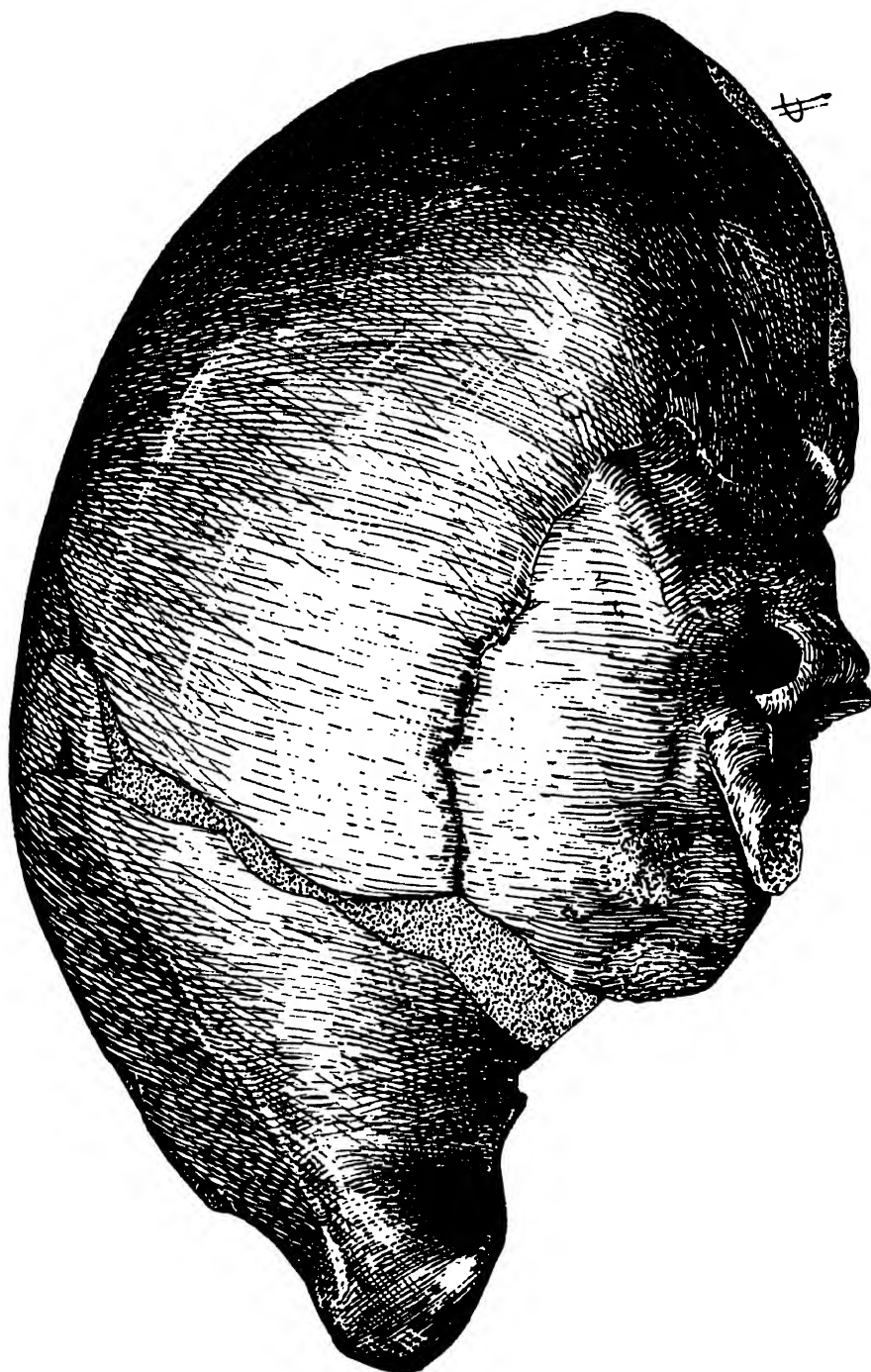


FIG. 1. *Pithecanthropus* II: the skull cap of an adult female, left lateral view. Natural size.
Front of skull (region of eyebrows) at left; back of skull at right. Auditory meatus near lower margin of illustration.

are much more definitely marked off from the tuber-like vaulted but otherwise also strongly receding forehead; and, on the other hand, the obelion region in *Sinanthropus* is flat, while in *Pithecanthropus* it is rounded off. The greatest similarity is seen in the structural form of the temporal and occipital bones. In this case, of course, only the Sangiran skull can be taken for comparison. The structure and the proportions of the temporal and occipital squamae and the direction of the zygomatic arch are the same. Absolute conformity in both *Pithecanthropus* and *Sinanthropus* is to be found in the location and form of the tympanic region, in the smallness of the fossa mandibularis, in the location and type of the ear opening, in the bending of the axis of the pyramid, and in the absence of a styloid process. The same is true of the development, course, and demarcation of the occipital torus and the construction of the planum nuchale. The only difference refers to the location and development of the mastoid, which in *Pithecanthropus* appears to form a part of the lateral wall of the skull rather than to represent a downward-directed process as is true in *Sinanthropus*. A total conformity is to be noted between the *Pithecanthropus* fragment III and *Sinanthropus* skull E; not only in that in the first mentioned the sagittal suture lies on a crest, but also that within the obelion region there is on each side of the suture a short groove which Black had already described and illustrated in skull E. Its significance cannot be interpreted.

"With regard to the lower jaws, that from Kedung Brubus is characterized as representing *Pithecanthropus* by the exclusively basal location of a broad digastric fossa—the only usable criterion. The mandible corresponds in size and proportions to the small female *Sinanthropus* jaws A and H and the more recently recovered mandible MII. The

jaw from Sangiran, on the other hand, is large and corresponds to the large male *Sinanthropus* jaws GI and KI, with the exception that the frontal section is not inconsiderably thicker than in the latter.

"The upper jaw from Sangiran has as yet no equal among the *Sinanthropus* specimens, for the two upper jaw fragments of the latter show much smaller dimensions and proportions, indicating that they apparently belong to female individuals, while the upper jaw from Sangiran must be ascribed to a male. But it does resemble the available *Sinanthropus* upper jaw in the pronounced total prognathism.

"The differences in size and proportions of the upper and lower jaws of both *Pithecanthropus* and *Sinanthropus*, apparently due to sexual differences only, also serve for a criterion of the cranial conditions in this respect. The lower and upper jaws from Sangiran are much too large for the small *Pithecanthropus* skulls I and II, whereas the lower jaw fragment from Kedung Brubus would seem to fit them much better. It may be concluded therefore that the two skulls, regardless of their minor differences in size and thickness, must have belonged to female individuals. The rather heavy *Pithecanthropus* skull IV undoubtedly represents an old male individual.

"With respect to the dentition, the *Pithecanthropus* molars are larger than those of *Sinanthropus* available so far. But the lower incisors—so far as the size of the crowns can be estimated from that of the alveoli—and especially the lower canines of *Pithecanthropus* are decidedly smaller than those of *Sinanthropus*. The canines of the upper jaw protrude considerably beyond the surface of the premolars, despite both being strongly worn. They conform in this respect to the *Sinanthropus* canines so far as the male individuals are concerned. Such can be inferred from the condition of an iso-

lated right upper canine and the following first premolar from the same site. Both these teeth are immature and show the same stage of development of their roots, having apparently belonged to the same individual. The pattern of the *Pithecanthropus* canine resembles that of *Sinanthropus* but is less complicated in that it lacks the cingulum so characteristic for the latter. These differences are also true for the premolars and molars. Not one of the *Pithecanthropus* teeth shows such primitive characteristics as are found in teeth of *Sinanthropus*. *Pithecanthropus*, therefore, undoubtedly stands in this respect at the upper boundary of the range of variation approaching the Neanderthal types. On the other hand, *Pithecanthropus* is of a more primitive nature than *Sinanthropus* in that the second molar of both upper and lower jaw is distinctly larger than the first, and the third lower molar the longest of the three. In addition, it is evident that—the first known example in a fossil hominid—the upper canines of both sides are separated from the lateral incisors by a broad diastema the width of which amounts to 6.2 mm. on the right side. This width comes close to the average width known for male gorillas and corresponds to that of male orang (average width, according to Remane, 6.8 and 6.2 mm. respectively).

"The dental arch of the *Pithecanthropus* upper jaw is long and relatively narrow (maxillo-alveolar index 88.2–92.0 ?). The front teeth, as inferred from the alveoli, were ranged within a curved line and directed forward, whereas the molars form two straight and backward-diverging rows. The frontal arch of the lower jaw shows a similar form but the row of molars displays a slightly outward-directed convexity. The upper dental arch of a male *Sinanthropus* is not available, and that of the female, as in the lower jaw, lacks a diastema, with the molar row forming a slightly outward-curved arch.

"Thus, all the skeletal remains and teeth of *Pithecanthropus* and *Sinanthropus* so far available prove the close relation between the two types.

"With respect to the affinity of the Trinil femora, it must be taken into consideration that the seven femora of *Sinanthropus*, most of which are represented by shafts only, show, in contrast to other skeletal parts, significant differences when compared with the Trinil specimens. All the *Sinanthropus* femora display a marked degree of platymeria and a very low pilaster index. They are relatively short and broad and exhibit certain characteristic peculiarities of the upper end. The supposed *Pithecanthropus* femora, on the other hand, are long and slender with no indication of being platymeric, and have high pilaster indices. They fail to show differences of any kind from this bone of recent man. All this argues against the possibility of their belonging to *Pithecanthropus*.

"*Pithecanthropus* and *Sinanthropus* undoubtedly represent the most primitive hominid forms known hitherto which, according to Boule, may be ranged collectively under the name Prehominids. Which of the two types must be taken to represent the more primitive form cannot be decided with certainty for the present. Fragments of *Sinanthropus* skulls suggest that here there were individuals whose capacities did not exceed that of *Pithecanthropus* II (*Sinanthropus* skull "J" II), and, on the other hand, individuals with a long and rather low cranium such as the *Sinanthropus* skull fragment H III reveals. In any case, it is certain that *Pithecanthropus* shows some characteristics which must be considered more primitive than those evident in *Sinanthropus* (for example, the structure of the pars mastoidea of the temporal bone and the occipital parts of the skull, the proportions in size of the molars, and the presence of diastema in the upper jaw). The primitive traits characterizing *Sinanthropus*, on the other

hand, consist in the manner of connection of the supraorbital ridges to the forehead, the more strongly developed frontal teeth, especially those of the mandibles, the persistence of a cingulum, the consistently strongly developed talonid of the premolars, the appearance of the trigonid in the molars, and the more complicated pattern of all the teeth.

"Considered as a whole, within the prehuman group *Pithecanthropus* and *Sinanthropus* show the same relation to each other as may be expected of two different races of present mankind which may also display different primitive characters, each having taken its own course in evolution.

"The prehuman *Pithecanthropus* and *Sinanthropus* are separated from the Neanderthal group by a considerable gap. On the other hand, an apparent close relation may be observed to exist between *Pithecanthropus* and *Homo soloensis*. The skulls of the latter appear like an enlarged form of those of *Pithecanthropus*. Even such peculiarities as the continuation of the supraorbital ridges into the forehead, the eminentia bregmatica, the structure of the obelion region, the special form of the ear opening and the tympanic part, and the bending of the axis of the pyramis reappear in *Homo soloensis*. Traits which suggest an already more advanced type, such as the greater cranial capacity, the size and structure of the mastoid process and the occipital torus, and the form of the planum nuchale, deviate from the conditions found in *Pithecanthropus* and are similar to those of typical Neanderthal forms. All this suggests that *Homo soloensis* must be considered an advanced *Pithecanthropus* type. Such common traits as may be found in *Pithecanthropus* and *Sinanthropus* will, of course, also be noted in *Homo soloensis*. The two available fragments of the tibia of the latter show no peculiarities, with the

exception of a pronounced platymeria, and have recent human characters in their entire construction.

"The finds reported herein show that Java has become the most important center for the study of prehuman forms. Not only prehumanids but also the following evolutionary stage, in close relation to the Neanderthal man (*Homo soloensis*), are represented there. Furthermore, we know that the Wadjak of Java represents another early form of recent man whose upper jaw (Wadjak II) in the construction of its frontal part displays a most surprising resemblance to the *Pithecanthropus* upper jaw." (The paper "On the relationship between *Pithecanthropus* and *Sinanthropus*," from which these excerpts are quoted, will be published in *Nature*.)

In Hongkong Dr. von Koenigswald collected more material of the Kwangsi cave fauna from the Chinese drugstores. The most interesting specimens are a third lower molar of *Gigantopithecus* and a premolar of fossil man. The *Gigantopithecus* molar is 22.3 mm. long and (slightly worn) not less than 12 mm. in height. The pattern is very complicated, owing to complications of the cusps, and not of the surface only as in orang. The worn human premolar is very large, 9.4 mm. anteroposterior diameter and 10.5 mm. transverse diameter, and surpasses the maximum as known in modern man. As such big premolars are very typical for *Pithecanthropus* and *Sinanthropus*, we must conclude that this fossil man of the lower Pleistocene Orang fauna of southern China belongs to the same group. Big molars, already found—a lower molar is 14 mm. long—also show affinities to *Sinanthropus*, but have a less complicated pattern besides other differences.

In the Patjitan region (Central Java) more primitive hand axes and fossils from the rock fissures have been collected.

STUDIES OF GEOLOGY AND ARCHAEOLOGY
RELATING TO THE ORIGIN OF
MAN IN ASIA

H. DE TERRA

With financial aid from the Carnegie Corporation of New York, through the Carnegie Institution of Washington, it has been possible to continue these studies and engage in the preparation of a final report.

Investigations of a geologic and archaeological nature concerning the evolution and environmental problems of early human cultures in southern Asia which were carried out last year in cooperation with the Peabody Museum of Harvard University and the Academy of Natural Sciences at Philadelphia have led to a few new conceptions in the field of Pleistocene stratigraphy and cultural typography. From work on the field notes and study of the collections of soil samples, fossils, and paleolithic artifacts, it appears that the results of the last expedition touch on fundamental questions pertaining to the age determination of early human cultures, to the geology of fossil soils in tropical regions, and to the manufacturing methods of prehistoric tool making.

As to age determination, the great difficulty so far has been to find a stratigraphic scheme which was precise but flexible enough to permit of application in the nonglaciated regions of the northern hemisphere. In most cases the study of Pleistocene stratigraphy has been carried on either by a paleontologic method, i.e., by establishing successive life zones in superimposed strata, or by petrologic classifications of rock sequences. While the latter can rarely be regarded as anything but local soil geology, the former lacks universal validity because of the fact that Pleistocene mammal associations are relic faunas adaptable to their respective habitats. This is particularly true for the tropics, where the Pleisto-

cene fauna was not subjected to such rigorous climatic changes as in the glacial and periglacial regions. For instance, while in Asia and Europe the three-toed horse (*Hipparion*) became extinct in the Pliocene, it continued to exist with other relic forms in East Africa, where it appears in the fauna associated with fossil man (Upper Pleistocene). Similarly, the genus *Stegodon* is present in Java throughout the Pleistocene, while in India and China it became extinct in the Middle Pleistocene. Also the much-inflated theory as to the existence of "cold" and "warm" faunas in Ice-Age Europe can hardly be upheld any longer in view of recent critical studies by Kormos, Penck, and others, according to which the reindeer and lemming, two supposedly outstanding "cold" forms, are rather abundant in interglacial strata (warm period). Hence mammals do not make good guide fossils for the Pleistocene of Eurasia, and this limitation of the paleontologic method compels a new line of inquiry. This is provided by what one might call the "multistratigraphic" method of Pleistocene geology. This is graphically illustrated by figure 1. Three amplitude curves are given, showing: (A) mean temperature of the Pleistocene period in Asia (Himalayas); (B) approximate amplitude of sedimentation; (C) approximate amplitude of diastrophism. All three are referred to the time coordinate as estimated by Milankovitch. In A, four glaciations (G) are represented by temperature minima based on the position of the respective snow lines, particularly on that of the last glaciation, which Penck calculated to have been caused in Europe by a drop of 4° Celsius in average temperature. The minima (G3 and G4) are marked by deposition of glacial soils (older and younger loess of central Europe). In B, amplitudes (P) signify comparative thicknesses of coarse sedimentary columns (gravel-sand) between 35° and 20° north latitude in south-

ern Asia. Their respective positions on the time coordinate are approximate only, but are revealed by the geologic succession as it is known from the submontane valleys and plains of the Mediterranean mountain belt in Eurasia. Horizontal ruling indicates accumulation of fine-grained sediment which is partly of aeolian origin. Curve *C* shows three paroxysms of mountain uplift as manifested by structural and physiographic data. There are three phases of paroxysms, of which the latest (upper Pleistocene) has two subphases which generally led to tilting of river terraces and loess deposits. These are subsequent

the phenomenon of four principal gravel zones (with corresponding soil sheets in southern latitudes) in the Pleistocene column. To the resulting four divisions must be added those which the abandoned river flats or terraces provide. These could hardly have survived the first two diastrophic phases, which must have caused destruction of any existing terraces. This, then, explains why along the Alps in Europe and around the Himalayas in Asia terraces date back only to the second interglacial. The oldest ones are generally dissected or tilted owing to subsequent denudation (third diastrophic phase). Where the terraces lie within

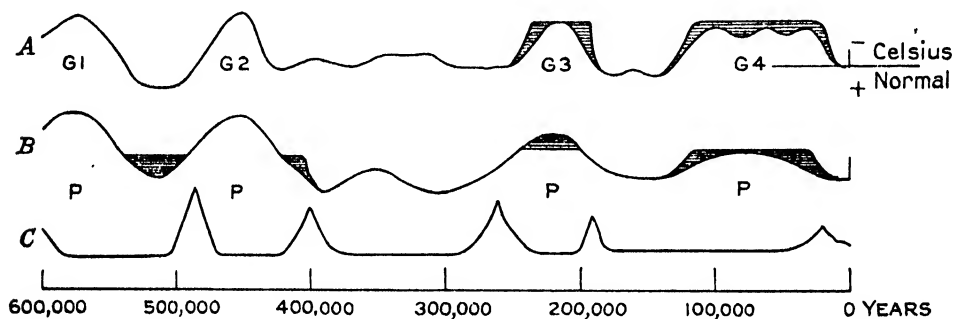


FIG. 1. Amplitude curves showing determinants of Pleistocene sedimentation in submontane tracts of Eurasia. For explanation see text.

to the orogeny of the Tertiary period, and signify the crustal mobility peculiar to the eastern portion of the Mediterranean mountain belt.

A comparison of the three curves shows a distinct correspondence between *A* and *B*; that is to say, between glaciations and accumulations of coarse deposits especially in the tropical regions. The explanation for this relationship has to be looked for in the effect which a drop in air temperature must have on precipitation in the submontane tracts of our high mountain belts. Condensation of air moisture on the one hand and intensification of the submontane rain belt (due to the rise of a barometric high over the glaciated tract) should suffice to explain

reach of mountain glaciations and uplifted zones, there are usually five, the latest of which is of post-Pleistocene age. Such terrace systems have already been traced from central Europe across Asia Minor to central and southern Asia. The enormous extent of this stratigraphic composition can hardly be explained other than by this correspondence between climatic and geologic determinants of Pleistocene sedimentation. This is made evident also through certain soil associations which can be explained only by climatic changes (see the writer's Burma report).

A comparison of *B* with *C* shows agreement with the law according to which mountain uplifts release rock detritus,

causing accumulation at the next base level of erosion. At the same time curve C shows that this correspondence is not complete as far as subphases of diastrophism are concerned.

This stratigraphic scheme is one in which fossils play only a secondary rôle, though obviously they should always be consulted as an aid for checking age determinations gained from other sources. The implications arising from such a scheme in regard to dating and correlation of early human remains will be discussed elsewhere.

With this we come to the second new point which our studies have revealed in regard to early man. The discovery of a new focus of dispersal for the early paleolithic cultures in southern Asia presents a new question as to the evolution of tools. From the writer's study of European collections it would seem that both the hand axe and the hand adze are chance products depending on the raw material from which they were made. In Europe and Africa hand axes dominate in the Paleolithic because flint is plentiful in the Pleistocene formations. In the East, on the other hand, where chiefly quartzite, quartz, fossil wood, or silicified tuff was used, most of which do not permit of good flaking, the principal tool type is the pebble chopper or hand adze (term applied by Dr. H. L. Movius to early paleolithic chopping tools). It remains to be seen whether such distinctions are of any other than typologic significance.

Work on these problems is still under way and a volume is being prepared dealing with the results of the Southeast Asiatic Expedition of 1937-1938. In this task several specialists have kindly consented to cooperate. They are: Dr. Edwin H. Colbert of the American Museum of Natural History, for the vertebrate fossils; Dr. H. A. Pilsbry of the Academy of Natural Sciences, Philadelphia, for the invertebrate fossils; Dr. P. D. Krynine

of the Soil Laboratory, Pennsylvania State College, for the soil samples; and P. Teilhard de Chardin, our field collaborator since 1935. Dr. Movius of the Peabody Museum of Harvard University is working on the archaeological material, of which there are several thousand specimens.

With the publication of the first volume (*Studies on the Ice Age in India and associated human cultures*, by H. de Terra and T. T. Paterson, Carnegie Institution of Washington Publication No. 493), the results of the first field season are now presented. Part of these were shown graphically on the occasion of the annual exhibition of the Carnegie Institution last December. This was the first time that results from these Asiatic researches, including Dr. von Koenigswald's work in Java, were shown.

STUDIES IN HISTORICAL GEOLOGY IN SOUTHERN CALIFORNIA

J. P. BUWALDA

Parts of the Tehachapi Mountains, connecting the Sierra Nevada and the Coast Ranges of California, were investigated further during the past year with a view to gaining information regarding their structural history. Since some at least of the structures of the Tehachapi region are related to those of the Coast Ranges, the information secured would bear on the tectonic history of the latter region.

Much or most of the deformation of the Coast Ranges is generally held to have occurred late in the Tertiary and during the Quaternary. A large east-west fault in the Monolith district of the Tehachapi Mountains demonstrates beyond doubt that intense deformation affected this area earlier, at some date between early Tertiary and lower Miocene time. The fault is a thrust in which granitic rocks have moved northward on a fault surface of moderate inclination,

sloping 30° to 45° southward, over strata the exact age of which is in doubt but which are quite certainly post-Cretaceous and in all probability are lower Tertiary. These strata of the Witnet formation have been strongly folded, and are overturned northward at the fault. The overlying Kinnick formation, unconformable on the Witnet and of lower Miocene age, is not similarly deformed by the faulting, indicating that the fracturing occurred in pre-Witnet time. The eastern end of this fault has been explored recently and its trace at the surface is found to end against a cross fault which drops down the block to the east of it. The surface rocks east of the cross fault are parts of the Kinnick formation and are not cut by the fault nor are they visibly deformed by it. They therefore bear out the conclusion that the overthrust is lower Tertiary and pre-lower Miocene in age.

Another structural feature investigated in the field is the suspected nonconformity between the Kinnick formation, containing the Phillips Ranch vertebrate fauna, and the overlying Bopesta formation, containing the Cache Peak fauna. The faunas represent quite widely separated stages of the Miocene and the formations should be separated by a marked structural break. A strong change in lithologic character occurs at the boundary, from the volcanic series of the Kinnick to the terrestrial sediments of the Bopesta. Suggestions of angular discordance were found during the recent field studies, but additional detailed field mapping will be required to demonstrate definitely the presumed existence of an angular unconformity.

The date of the movement on the east-west overthrust fault intimates strongly that vigorous deformation occurred in the Coast Ranges to the west in lower Tertiary time, and the considerably folded lower and upper Miocene Kinnick and Bopesta formations indicate that this

part of the Sierran block did not remain relatively rigid during the Tertiary like the middle and northern parts, but was affected by the folding and faulting of the Coast Ranges to the west.

Some advance was also made in the investigation of the Sierra Madre fault zone along the south base of the San Gabriel range. More detailed work was done in the section around the mouth of the Arroyo Seco, which extends westward the Mount Wilson portion of the front lying between Altadena and Sierra Madre, studied earlier. The pattern of the faults in the Arroyo area is astoundingly complex, including faults that strike northwestward back into the range as well as a series of subparallel fractures first diverging and then converging westward and dropping slices and wedges to form the deep and broad re-entrant in the mountain from which the stream issues. The character of the pattern here tends to corroborate the inference reached earlier, that the movement along this fault zone is dominantly vertical and does not involve an important horizontal component such as characterizes the San Andreas and other northwest-southeast faults of southern California.

STUDIES ON THE ARCHEAN OF THE GRAND CANYON

IAN CAMPBELL AND JOHN H. MAXSON

Owing to the necessity of moving the Geology Department, with its equipment and extensive collections, into new quarters at the California Institute of Technology, there was little opportunity for field work during the summer and fall of 1938. Dr. Maxson, however, prepared and carried back to Washington an exhibit illustrating the Grand Canyon Archean research, for the annual Carnegie Institution exhibition.

In December, Dr. Campbell, accompanied by E. T. Schenk of the National Park Service and Dr. W. E. Powers,

undertook some field work in the vicinity of Lake Mead, and especially in the Toroweap area on the north side of Grand Canyon. This work was an extension of observations on intercanyon lava flows made during the Canyon traverse in 1937. Earlier workers have suggested that Vulcan's Throne, or other nearby volcanic cones, might have been the source for basaltic lavas that may have poured over the edge of the Grand Canyon and then flowed down the channel for nearly 100 miles. On the basis of the present observations, such a hypothesis appears unlikely, although complete data are not yet available. There are other interesting and puzzling features connected with this epoch of Canyon history that remain to be investigated; for example, why, since there was sufficient magmatic pressure to force the lavas from an unknown underground source through at least several thousand feet of strata vertically, was there not force enough to cause a lateral movement of only a few hundreds of feet, thus permitting the lava to erupt at an intermediate level, in the canyon walls? Other volcanoes are present on the south side of the canyon, and they should be investigated before any final answers to these problems are formulated.

Problems of intrusion and metamorphism in the vicinity of Lake Mead have been investigated, where the picture is complicated by the presence of two distinct ages of granitic invasion—Pre-Cambrian and (presumably) Jura-Cretaceous—and of relatively recent volcanism.

Meanwhile laboratory studies of the extensive collections made on previous expeditions have gone forward. Some further work on the interesting problem of Archean calcareous concretions has been done; tourmaline dikes—a feature of the Archean near 96-Mile Creek—are being studied. Specimens of the curious crenulated structure occur-

ring on quartzite near Monument Creek and previously reported as ripple mark were made available to Dr. Earl Ingerson of the Geophysical Laboratory, in connection with his petrofabric investigations of sedimentary and metamorphic sediments. On the basis of Ingerson's work, it is now virtually certain that this structure is entirely of metamorphic origin, and should be described as "pseudo ripple mark." Dr. Maxson, accompanied by Dr. H. J. Fraser of the California Institute and E. D. McKee of the National Park Service, revisited the locality near Monument Creek in May 1939, for the purpose of rechecking the field structures and of getting additional material. This investigation again illustrates the fruit of cooperative effort between the different fields of research of the Institution. Indeed, on the basis of Ingerson's findings, it should prove profitable to re-examine all the earlier reported Pre-Cambrian ripple marks, examples of which have been recorded from Canada and Fennoscandia.

On lithologic and stratigraphic grounds we have previously suggested that the Grand Canyon Archean may be early Pre-Cambrian. Recently, a specimen of a pegmatite was submitted to Professor Robley D. Evans for age determination by the helium method. The report on this determination follows (Clark Goodman, letter, July 26, 1939):

The quartz and feldspar in the specimen were sorted out by hand and the helium and alpha activity measurements made on these separate portions. The small amount of magnetite present was discarded. The following observations resulted:

Sample	He (10 ⁻⁸ cc./gm.)	Activity (α /hr./mg.)	Age (mil- lion years)
Quartz	0.95 \pm 0.15	0.15 \pm 0.04	200 \pm 50
Feldspar . . .	0.84 \pm 0.10	0.125 \pm 0.02	210 \pm 40

An age of 200,000,000 years would seem to place the granite later than the Archean. However, it is pointed out by

Drs. Evans and Goodman that the true significance of the determination is uncertain. A number of specimens should be analyzed before any conclusion is reached. It is hoped that a more definite correlation on the basis of a large number of determinations may be available in the future.

In addition to the individuals cited

in the foregoing report, who have contributed to the program, it is a pleasure to acknowledge the continued interest and cordial cooperation of the U. S. National Park Service, particularly through Dr. H. C. Bryant and E. D. McKee at Grand Canyon and Messrs. G. D. Edwards, R. H. Rose, and E. T. Schenk at Lake Mead.

G. R. WIELAND, Yale University, New Haven, Connecticut. *Cycadeoid investigations with respect to Fossil Cycad National Monument*. (For previous reports see Year Books Nos. 34, 35.)

A simplified account of the course and stage of research in a recondite subject is ever and anon a necessity. Simplification is the primal objective. To the investigator clarity of view is the first necessity. Over and above him the educational phase is reached. What is done once and for all may be briefly told. Thus what at times seems an all but endless vista of the unknown (such as is paleontology in even its finer subdivisions) is ever being bounded anew, narrowed down, or else aligned for further attack. In the case of cycadeoid investigation, no better time than now after several years without report, but with new facts and points of view reached, might be set for discussion. These investigations as they have concerned us have lasted through the entire history of the Carnegie Institution and have been as all now stands peculiarly a Carnegie venture. Far more, they have with the advantage of this steady continuity lasted long enough for others to make again and again most distinguished contributions to both fact and method. This is science at its best—not dependent on any one investigator, or country.

In earlier reports more or less detailed mention was given to recent advance in technique as applied to petrified plant study. After the publication of volume II of *American fossil cycads* we found

ourselves face to face with collections of a defying extent and difficulty of study. This seemed to inhibit for a time the setting aside of the modest sums needed for laboratory and field, even on the old lines. It was difficult to make others see that new collections might shorten the course of the cycadeoid researches instead of merely lengthening them out. All that has changed, however; so that no further word need for the time being be given such subjects as abrasives and abrasive hazards, or etching and cutting.

We see in the cycadeoids the outstanding plant types of the Mesozoic world. Adposed are the dinosaurs. Always in any effort to visualize the course of land life as far as it may be seen to change during Mesozoic times, the investigator turns to closer and closer study of dinosaurian life because the group throughout its history lent itself beyond all other contemporary life to a course of fossilization ending in a record almost unbelievably complete. The environmental effects are seen. The factors leading to extinction come into a brilliantly lit foreground. What is now known of the dinosaur may well outweigh the unknown a hundred to one. Yet the dinosaur has left not a single link in the chain of surviving vertebrate life. His peculiar distinction is nearness to avian life. Hence any mammalian relationship, except as

set far back in Paleozoic times, is all but precluded.

While, then, the cycads like the dinosaurs are each to each the outstanding types of the Mesozoic, there is a broad difference in the final evolutionary rôle of these great groups. The cycads, using the term in the broader sense, appear to give rise to true persisting lines. They come into view in early Triassic times in ever increasing numbers and then all through the Jurassic appear as dominants in numbers and even in variety of type. By lower Cretaceous times the cycadeoid vegetation is still very conspicuous, including especially much of the petrified record so much the subject of our research. Then the conifers make their greater deployment as specialized types, and the cycadeoids recede as the angiosperms come to dominate the forest canopies of all latitudes. And we dare to say that in most competent botanic opinion these very angiosperms sprang in the strictly ascendant sense from somewhere within the cycadeoid or flowering cycad complex, either early or late in geologic time. It is very improbable that this beginning of the angiosperms, this point of time when they once and for all parted from their ancient relatives, was earlier than the close of the Permian, or could have been by any possibility as late as the earliest Jurassic.

In the course of discussion during the Botanical Congress of 1930 at Cambridge, the eminent paleobotanist, D. H. Scott, made a remark to the simple effect that "an origin of the angiosperms from somewhere within the cycadeoid alliance was really the only point of view under the status of discussion." Nothing learned since alters that status. Much supports it—especially the acuter study of the floral morphology of the conifers, so long left in abeyance. And by now both wood structure and habitus are aligned in direct evidence, while foliage offers no difficulty. Even if, when the

much wished discovery of the wood in *Williamsoniella* and *Wielandiella* is once made, it turns out there is not the distinct semblance to *Tetracentron* or *Drimys* that we so fully expect, the argument would remain much the same, or even distinctly strengthened. For then it would merely appear that wood structure in the cycadeoids was as varied as befitted a long-time dominant flowering group.

In short, while the dinosaur is, somewhere early in his history, related distantly to the avian lines and to the flying reptiles, the cycadeoids are a relatively far less extinct stock, which we must believe had an actual and direct if primitive share in the evolution of the angiosperms. What yet lacks absolute proof here is floral. The flowers of the older angiosperms have not been seen. But that none of them, or not enough of them, may ever be found to enable us to gain a relatively clear picture of the defined course of floral change is unbelievable. From the writer's own field study of the Rhaetic of Argentina and the Jurassic of Mexico he is led to declare that a brilliant course of discovery yet lies before us. Much will depend on the methods of collection afield with reference to the subsequent laboratory study. Likewise the fact faces us that so far as bettered chemical methods of study go, the American Rhaetic flora of Virginia and North Carolina is nearly as much an incognita as the South American record. In all these regions, then, the conditions of fossilization are peculiarly favorable to the preservation of delicate cone and even floral features which we may hope to discover once study becomes acute. Here is a brilliantly lit field for the research institution.

The near objectives. Because the petrified stems of the cycadeoids are seen in widely variant conditions of fossilization and stages of growth, the limits of actual or natural species are

exceedingly difficult to define. Nor is it necessary, in our effort to reach the larger evolutionary viewpoint, our real first objective, to set the specific limits immediately. That rather becomes the task of some far future day. What is first in need of demonstration is the structural range, both vegetative and reproductive, with the closest attention to habitus. Here too the surest and best-set line of approach is pictorial. That these elemental facts are fully admitted or fully understood by the student could easily be proved to be much in doubt. However, as the needs in cycadeoid investigation were faced, the need and use of a field demonstration at the Minnekahta locality, now the Fossil Cycad National Monument, shortly came into clear consideration. This venture is a combined scientific and educational objective. Because it includes stratigraphic, chemical, and the highest evolutionary values all in one, the proposed development must in the fullest sense be regarded as an economy measure and plan.

As related in Year Book No. 35 (1935-1936), pages 335-336, over one ton of the finest specimens was secured in the course of excavation on the Monument front in November 1935. Recently, the main portions of this unique collection were forwarded to the writer at Yale for the purpose of illustration with sectioning for final display. As far as resources have allowed, this initial study has been carried forward.

The new material alone would make a most brilliant display for the proposed museum, plans for which are at last before us. Here we shall see for the first time in the history of cycadeoid investigation uneroded specimens in series, along with the exact points of occurrence in a clearly marked foreground. Some of the trunks seem to have been petrified where they grew, while others perhaps

floated about a bit near the edge of the flood plains marking the close of the filling in of the early Cretaceous (or perhaps closing Jurassic) lacustrine basin. Never before have the lesser branched types like the *Cycadeoidea nana* and the *C. anomala* been seen in this uneroded and unbroken perfection.

Also, two very large stems, plainly of the same species and at least provisionally referable to *Cycadeoidea colossalis*, are seen to bear a fine series of seed cones. Together they make one of the most strikingly paired exhibits ever recovered, showing exactly the transition from columnar to branched types, the one stem being strictly simple and unbranched, the other but once branched like a heavy letter Y. Whence in these types any use of branching or nonbranching as either a specific or a generic distinction would mean facing a contradiction.

The very much branched low set clumps of the *Cycadeoidea nana* type are of a peculiar interest because here we deal not alone with the freest branching yet seen, but with very small frond types. From six to eight branches are sometimes present; and most curious is the presence of later growth from beneath more apical branches, so that there is a close approach to a rootstock, these later growths not being wholly above or outside the root zone. Here again, by contrast, in the very closely related species *Cycadeoidea anomala* the form may be decidedly columnar with only very minor branching. Conformably to this more slender stem habitus with less foliage, the wood zone is heavy and the cortex thin. That all these features are here seen in such wealth of illustrations makes it strange indeed that branching in the heavier-stemmed cycadeoids should be so rarely found, taking the world over. None the less, no one may say that there were not in the old cycadeoid alliance types as strangely branched, small-

leafed, and small-flowered as in some modern *Tamarix*.

Methods of study. In arranging for exhibit and bringing into a strictly scientific foreground the unique collection of 1935, the first need is illustration in a quarto portfolio of plates, for which negatives are mostly ready. Unfortunately certain important specimens of the series excavated have been lost to view as far as can be learned, and these specimens had not been photographed. In the course of time papier-mâché models of rarely significant single specimens may easily be had by all who care to meet the slight cost. Likewise, when the first needs of investigation have been met, thin-section series may become available. As the first hundred years of cycadeoid study come to a close this is what teacher and public alike need to be told. Here, the isolated specimen means but little. The collections must stay intact.

Obviously our investigations take on a far-extended range. They center about the record as seen in the Black Hills, as much attention as practicable or possible being next given to other extensions of the petrified series as seen in the Arundel of Maryland, the Trinity beds of Texas, the Mesaverde, and yet other more scattered occurrences. From this primary viewpoint, much-needed study and illustration has been brought forward as far as available resources permit and is reasonably near the point of publication. The effort has been made, too, to bring the European record into near comparison. In particular there has been published a good series of drawings intended to fit the needs of teachers and textbook writers. Not infrequently these drawings are used in "redrawn" form when it would be cheaper and better merely to reproduce them as line drawings.

To illustrate this latter point, it is wished to mention here what may be

called a transdissection of the *Cycadeoidea dacotensis* flower bud—though of course in photographic form only. Taking the enlarged photograph of one of the finer thin sections and cross-comparing, the features were first marked out line by line. Then the several parts were all cut out, remounted with space between, and thus rephotographed. The result is absolutely accurate, in simple clarity, a *sine qua non*. The next step is to secure well enough silicified examples of more-reduced flower buds to permit further such transdissections of less-known species.

In the effort to reach satisfactory results, it is very pleasing to mention the fact that the eminent French paleobotanist Paul Bertrand has expressed his wish to join in the search in the forested region of the Galician Carpathians, which still holds hidden the nearest European complement to the American cycadeoid record. There is at least the lively hope that such an intensely alluring try "in the field" may soon reach fulfilment. Moreover, there was recently forwarded to the writer at Yale a core cut from near the summit of the Carpathian type long known and correctly named *Cycadeoidea niedzwiedskii* by Maryan Raciborski. The specimen was sent by Dr. J. Lilpop from the Physiographic Museum of the Polish Academy of Sciences, Cracow. This axis has been cut and at last proves that this species too is in closest structural agreement with the medium-sized and less-branched types from the Fossil Cycad National Monument mesa. As a "species" it dates from the same year and month (October 1893) as the first of that series, *Cycadeoidea dacotensis*. It is therefore a valid prior species. The seed cone is so close to our Monument types as to leave several of them barely separable specifically.

So that once more this exceedingly

close Black Hills-Carpathian cycadeoid parallel comes into full view as a subject of the finest educational value and international interest. Cooperative development of this project, bringing to bear the

widest experience in laboratory and field, as both Professor Bertrand and Dr. Lilpop so definitely propose, surely must lead to discovery and demonstration anew.

PHYSICS

COMMITTEE ON COORDINATION OF COSMIC-RAY INVESTIGATIONS. *Progress report for the period July 1938 to June 1939.* (For previous reports see Year Books Nos. 32-37.)

The Committee was appointed in December 1932 by President Merriam to consider coordination of possible continued financial support through the Institution for cosmic-ray research. Previously the Institution had supported in part, largely through individual grants provided by the Carnegie Corporation, certain cosmic-ray investigations, notably by Dr. A. H. Compton, Dr. R. A. Millikan, and others.

From 1932 the Committee, in the establishment of a program and in consideration of projects submitted, has enjoyed the privilege of consultation either through personal contacts or through correspondence with the following and many other interested investigators: C. A. Anderson, California Institute of Technology; J. W. Beagley, Christchurch Magnetic Observatory; R. D. Bennett, Massachusetts Institute of Technology; H. A. Bethe, Cornell University; P. W. Burbidge, New Zealand Department of Scientific and Industrial Research; A. H. Compton, University of Chicago; D. la Cour, Meteorological Office of Denmark; S. E. Forbush, Carnegie Institution of Washington; J. Gallo, National Astronomical Observatory of Mexico; V. F. Hess, University of Innsbruck and Fordham University; R. M. James, University of Cape Town; T. H. Johnson, Bartol Research Foundation of the Franklin Institute; R. A. Millikan, California Institute of Technology; H. R. Mimno, Harvard University; H. V. Neher, California Institute of Technology; W. N. Nielsen, Duke University; L. W. Nordheim, Duke University; A. Ogg, University of Cape Town; M. S.

Vallarta, Massachusetts Institute of Technology.

These consultations early showed that, while geographical reconnaissance in cosmic-ray research through isolated observations for short periods yielded profitable results, the then chief desideratum was precise and continuous series of records at several fixed stations, for which precision instruments and cooperative endeavor should be provided. Stations for which data obtained continuously and simultaneously for long periods might be suitable for statistical analysis must be reasonably well distributed. Precision results were needed to answer such questions as those concerning the definite reality of possible seasonal effects in different localities, of solar-day, lunar-day, and sidereal-day variations, of day-to-day changes, of world-wide changes, etc.

The second desideratum was additional data in the higher atmosphere, where—because no known means permitted continuous records for long periods at various levels—numerous determinations above different points on the Earth's surface should yield material suitable for analysis and discussion.

A third desideratum was parallel coordinated research in the laboratory to facilitate understanding and interpretation of cosmic radiation. While this approach is provided by some individual investigators at universities, it too requires coordination and additional support for application to the general problem. The Committee has supported this approach to the extent of about half its available funds. Excellent progress in

theoretical studies, in interpretative discussions, and in instrumental technique has resulted. The work at California Institute of Technology and at the Bartol Research Foundation affords good examples of this.

Therefore, it appeared that, in general, the most effective coordination of effort, within limits of available funds, would concern observations and interpretative studies which require cooperation of research organizations, laboratories, and observatories.

Important problems requiring widespread coordination and cooperation include investigation of the nature of the radiations involved and the relations to the Earth's electric field, of variations of cosmic rays and the possible part played by them in the maintenance of the Earth's negative charge, and of relations to the 24-hour universal wave in diurnal variation of potential-gradient, to thunderstorm-centers, and to geomagnetic disturbances and singular features. Therefore recording stations were indicated at or near existing observatories recording continuously geophysical phenomena in atmospheric electricity, earth-currents, geomagnetism, meteorology, variations of the ionized regions of the upper atmosphere, solar activity, etc.

The Committee, therefore, first planned to provide recording instruments of suitable sensitivity. Professor A. H. Compton of the University of Chicago and Professor R. D. Bennett of the Massachusetts Institute of Technology generously cooperated in the design of a precise cosmic-ray meter, of which seven were constructed for the Committee at the University of Chicago. Pending the completion of these meters, arrangements were made for cooperation of (1) the U. S. Coast and Geodetic Survey at its Cheltenham Magnetic Observatory, (2) the Carnegie Institution of Washington at its Huancayo Magnetic Observatory,

(3) the Department of Scientific and Industrial Research of New Zealand at its Christchurch Magnetic Observatory, (4) the National Astronomical Observatory of Mexico at its station at Teoloyucan, and (5) the Meteorological Office of Denmark at its Godhavn (Greenland) Magnetic Observatory. Each of these organizations has now installed precision cosmic-ray meters provided by the Committee, and the meters are in continuous operation. Each of the organizations has provided without cost the necessary personnel, and in addition the Danish Government made an allotment equivalent to \$2500 to realize the cosmic-ray program at Godhavn. Besides the five meters thus placed, one has been set aside for purposes of standardization and comparison at the University of Chicago and another for special work on cruises of vessels in the Pacific and Atlantic Oceans from the northern hemisphere to the southern hemisphere. Plans are under way to install the latter meter near Climax, Colorado (12,000 feet above sea-level), to study cosmic-ray variations at high altitudes in connection with the installations at Huancayo (11,000 feet above sea-level) and at Teoloyucan (7500 feet above sea-level). Some aid was given to the University of Cape Town (South Africa) in order that several years' operation of the Steinke cosmic-ray meter there might be continued during the first years of registrations at the five observatories above mentioned, with a view to effecting a comparison of the two distinct types of meter.

It was arranged that the upper-air investigations of cosmic radiation by Millikan and associates at the California Institute of Technology be paralleled by similar investigations by T. H. Johnson at the Bartol Research Foundation, and by S. A. Korff, first at Washington at the National Bureau of Standards and the Department of Terrestrial Magnetism

and subsequently at the Bartol Research Foundation. Grants were recommended and provided for field-work at many widely separated stations.

The Committee has undertaken, through the appointment of several physicists, the reduction and discussion of the data accumulated both at fixed stations and at field-stations. These have already led to important statistical results on the solar, sidereal, and annual variations, on bursts, and on world-wide changes in cosmic radiation.

The collaboration of the National Bureau of Standards, the U. S. Weather Bureau, and the Bartol Research Foundation of the Franklin Institute with the California Institute of Technology in the upper-air measurements of cosmic-ray intensity has forwarded the instrumental technique of meters suitable for pilot-balloon flights, the results of which are communicated to a receiving station by radio. The Geiger-counter technique has been developed on the one hand by Dr. Millikan and his associates and on the other by Dr. Johnson and his associates, the latter giving particular attention to directional distribution of cosmic radiation at great heights in the atmosphere.

The reports of the Committee, published annually in the Year Book of the Institution beginning with Year Book No. 32 (1932-1933), cover the activities of the Committee and the details of the researches accomplished by those men to whom grants have been made. It is only to be added that all concerned in the investigations reported have evinced the desire not only to cooperate, but also, through coordination of effort, to make the most effective use of available funds.

The following summary and appended reports give details of the year's results and progress:

Instruments. The Institution's precision cosmic-ray meters were continued in operation at the following stations: Cheltenham Magnetic Observatory of the

United States Coast and Geodetic Survey, meter C-1, George Hartnell in charge; Huancayo (Peru) Magnetic Observatory of the Institution's Department of Terrestrial Magnetism, meter C-2, F. T. Davies in charge; National Astronomical Observatory of Mexico at Teoloyucan, D. F., meter C-4, Dr. Joaquin Gallo in charge; Amberley Branch of the Christchurch (New Zealand) Magnetic Observatory of the Department of Scientific and Industrial Research of New Zealand, meter C-5, J. W. Beagley in charge; Godhavn (Greenland) Magnetic Observatory of the Danish Meteorological Institute from October 7, 1938, meter C-6, K. Thiesen in charge.

The installation of meter C-3 at Climax, Colorado has been delayed owing to difficulties in eliminating loss of argon. Dr. R. D. Bennett of Massachusetts Institute of Technology redesigned the packing bushings and succeeded in satisfactorily sealing the chamber. He has also improved and simplified the control-circuits for this meter. After comparison of this meter with C-1 at Cheltenham it is hoped it may be installed at Climax, Colorado (as indicated in last year's report) under the supervision of Dr. J. C. Stearns.

The ionization-chamber of meter C-5, at Christchurch, in which it was not possible to eliminate loss of argon, was replaced in November 1938 by the ionization-chamber of meter C-0, which had been used by Dr. Compton in his survey on the Pacific.

Professor R. M. James reports continuation of records by P. Gaskell of the Steinke apparatus at the University of Cape Town following receipt of new batteries from Germany.

Other instrumental details and developments, particularly to secure data in the upper atmosphere, are indicated in the reports which follow by Messrs. Forbush, Johnson, Korff, and Millikan.

Investigations. Mr. Forbush extended the analysis of the world-wide effect at different stations. He found that the cosmic-ray intensity is practically always lower for the five international magnetically disturbed days than for the five international magnetically quiet days of each month, which is in accord with the magnetic-storm effect. The 13.5-day and 27-day waves in cosmic-ray intensity are closely associated with those for character-figure and magnetic horizontal intensity. When tested statistically, the component of the 27-day wave which might be ascribed to an inclined solar magnetic moment was found too small to be significant.

The report of Dr. Johnson shows good progress in his study of the east-west symmetry of cosmic-ray intensity. He and Dr. Barry secured eleven balloon flights in the Canal Zone, using the triple-coincidence Geiger-Müller counter-apparatus. His analysis of the data obtained indicates that the mesons of the hard component are not produced by electrons but by some other type of positive particle, most probably protons. He prepared a summary of cosmic-ray investigations which was published in the *Reviews of Modern Physics* (October 1938). As the ninth Joseph Henry lecturer of the Philosophical Society of Washington he summarized recent advances in these investigations.

Dr. Korff devoted his attention (a) to single Geiger-counter measurements with reference to effects of solar flares and diurnal effects at high altitudes, (b) to comparisons of measurements by counters and electroscopes, and (c) to neutron-measurements through development of special counters and balloon flights.

Dr. Millikan and his associates continued their studies at the California Institute of Technology (a) measuring atmospheric temperature-effects at sea-level, (b) measuring cosmic-ray energy

entering the atmosphere at different latitudes, (c) developing high-speed Geiger-Müller counters, and (d) measuring energies, absorptions, and scattering of cosmic rays with cloud-chambers.

Mr. J. W. Beagley, at Christchurch, New Zealand, continued the compilation of data recorded there. The results, when taken in conjunction with those from Cheltenham, indicate that the variation with latitude of world-wide effect is probably symmetrical about the equator. Mr. Beagley is continuing his studies of magnetic-storm effect and of seasonal variation.

Throughout the report-year Mr. Forbush, who was on furlough from the Department of Terrestrial Magnetism, gave full time to the reduction, analysis, and interpretation of the cosmic-ray records from the Committee's five stations. From July 1, 1938 to December 31, 1938 he was assisted by W. R. Maltby, who then resigned to take a permanent position, and from March 1, 1939 by F. R. Eldridge, Jr.

Members of the Committee maintained contacts by correspondence and conference with Messrs. J. W. Beagley, R. D. Bennett, A. H. Compton, D. la Cour, S. E. Forbush, J. Gallo, T. H. Johnson, S. A. Korff, and R. A. Millikan. The reports which follow indicate briefly the satisfactory progress made. The year's progress is well evidenced by the publications of investigators associated with the Committee as given in the list of publications bearing on cosmic radiation.

The generous assistance given on all sides in the cosmic-ray program is noteworthy. Besides those specifically mentioned above, the Committee makes grateful record and acknowledgment to the directors and staff-members of the organizations which continued to extend their facilities for the program; these include the Danish Meteorological Institute, the National Astronomical Observa-

tory of Mexico, the New Zealand Department of Scientific and Industrial Research, the United States Coast and Geodetic Survey, and the Carnegie Institution of Washington.

W. S. ADAMS
J. A. FLEMING
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STATISTICAL INVESTIGATIONS OF COSMIC-RAY VARIATIONS

S. E. FORBUSH¹

Reduction of data. Scalings of hourly values of ionization, of bursts, and of barometric pressure, with independent checks, were kept current for Huancayo and Cheltenham, as also reduction to constant barometric pressure of the daily means of cosmic-ray intensity at Cheltenham, Huancayo, and Christchurch.

The reduction to constant barometric pressure of bihourly means of cosmic-ray intensity at Cheltenham for each day from March 1937 to June 1939 was practically completed. This material is now in form suitable for harmonic analysis of the diurnal variation for single days, which will permit investigations of the causes of the variability in and possibly the cause of the diurnal variation.

A complete analysis of all data received for October and November 1938 from the newly established cosmic-ray observatory at Godhavn, Greenland, was made to insure that the meter was operating properly. From this analysis memoranda were prepared for use at Godhavn.

Intercomparison of cosmic-ray meters. The simultaneous data obtained from two Millikan-Neher electroscopes at Kensington, which were compared (see last year's report) with those from the Compton-Bennett meter at Cheltenham, were used to compare two of the Millikan-Neher instruments. Although the range

in recorded ionization during the period of comparison was only about 6 per cent of the total, statistical analysis indicated that on the average the percentage changes in the two Millikan-Neher instruments were, within the small experimental uncertainty, identical. This result was independently tested by operating these two meters simultaneously for about one day, after removing each of the corresponding sections of lead shielding from both instruments. Difference in thickness of corresponding sections of shield was compensated by interchanging shields.

The percentage increase in ionization effected by removing all shielding was identical (about 100 per cent) for the two instruments, checking the previous result obtained by statistical analysis. The new procedure will prove useful in future comparisons of ionization-chambers which have the same wall-thickness.

Intercomparison of barographs at Huancayo. The reliable determination of the 24-hour wave in cosmic-ray intensity depends critically upon the phase of the 24-hour wave in barometric pressure. The latter in turn will be seriously in error unless the barograph is properly compensated for temperature.

Since installation at Huancayo in June 1936, the barometric pressure used for cosmic-ray reductions has been obtained from an ordinary Richard barograph. In March 1938 the installation of a Negretti and Zambra microbarograph at Huancayo, to facilitate Professor S. Chapman's investigation of lunar tides, provided data for checking the performance of the Richard barograph. Careful analyses of data for several months from these two instruments revealed serious discrepancies which were mainly due to improper temperature-compensation of the microbarograph; it was later returned to the maker for correction.

Using data obtained by an optically recording microbarograph designed and

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constructed at Huancayo by W. Culmsee and H. E. Stanton, it was later found that both the Richard barograph and the Negretti and Zambra microbarograph were subject to considerable hysteresis (because of friction). This necessitated comparison of the 24-hour and 12-hour waves in barometric pressure from the Richard barograph with those derived from the Culmsee-Stanton instrument, which was free of hysteresis. Fortunately, this comparison showed that the retardation, due to friction, in the phase of the pressure-waves from the Richard barograph was small enough to be safely neglected in the cosmic-ray reductions.

World-wide changes in cosmic-ray intensity. The investigation of world-wide changes in cosmic-ray intensity, the preliminary results of which were anticipated in last year's report, was completed and published in the *Physical Review* for December 15, 1938. The discovery that the major changes in cosmic-ray intensity are, except for the seasonal change, world-wide probably constitutes one of the most important results so far obtained in the program for continuous registration of cosmic-ray intensity, initiated by the Committee on Coordination of Cosmic-Ray Investigations of the Carnegie Institution of Washington.

Statistical analysis involving a new procedure for determining weights used in least-squares adjustments of the world-wide changes permitted a reliable determination of the relative magnitude of the world-wide effect at different stations. These data provide a foundation and test for quantitative theories for the effect.

The seasonal variations have been tentatively explained by P. M. S. Blackett on the basis of meson decay.

Some serious discrepancies in the monthly means of the world-wide component at different stations occurred at Huancayo during August 1938 to April

1939; these probably were caused by failure to keep the insulation of the meter adequately dry. The world-wide effect thus promises to serve also to check the stability of meters at different stations.

Cosmic-ray intensity and magnetic activity. For 21 of the 24 months from July 1936 to June 1938 the average cosmic-ray intensity at Huancayo for the five international magnetically disturbed days of each month was found to be lower than the average for the five international magnetically quiet days. In addition, considerable correspondence was found between the monthly differences, average for the five disturbed days minus average for the five quiet days, for cosmic-ray intensity and for magnetic horizontal intensity at Huancayo. Thus the cosmic-ray intensity is generally lowered on days when the magnetic horizontal intensity is decreased. This is consistent with the observed magnetic-storm effect, again indicating that these changes in cosmic-ray intensity are due to a component of the magnetic disturbance-field, external to the Earth. (Further discussion is given in a paper published in the fifth report of the Commission to Further the Study of Solar and Terrestrial Relationships.)

On the 13.5-day and 27-day variations in cosmic-ray intensity and their bearing on the solar magnetic field. Because of the magnetic-storm and world-wide effects in cosmic-ray intensity, the existence of *quasi-periodic* 27-day and 13.5-day variations would be anticipated. The recent calculations of M. S. Vallarta and O. Godart show that a *periodic* 27-day wave in cosmic-ray intensity would be expected if the solar magnetic-moment vector is inclined to the Sun's axis of rotation. Since the existence of a permanent solar magnetic moment is much disputed, the Vallarta-Godart theory is of especial interest as indicating one way in which the cosmic-ray data might

serve to establish the existence of the general solar magnetic field.

Accordingly, simultaneous cosmic-ray data for 34 solar rotations of 27 days each for Christchurch and for Huancayo were subjected to harmonic analysis for 13.5-day and 27-day periods. The results of tests showed that no statistical reality could be ascribed to the average apparent 13.5-day wave. The available data were in themselves inadequate to determine whether the 27-day wave was persistent or quasi-persistent. However, the variability in the 13.5-day wave and in the 27-day wave at both stations was definitely correlated. The variability in the 27-day wave in cosmic-ray intensity was found to be negatively correlated with that in American magnetic character-figure and positively correlated with that in magnetic horizontal intensity at Huancayo, Peru. Because of these associations it is quite certain that the 27-day wave in cosmic-ray intensity is mainly quasi-persistent. This association indicates that the 27-day quasi-persistent wave in cosmic-ray intensity results from the alteration of trajectories of cosmic-ray particles, produced by some external component (such as the Störmer ring-current) of the magnetic disturbance-field.

When subjected to tests in a Bartels harmonic dial, the component of the observed 27-day wave, which might be ascribed to an inclined solar magnetic moment, is found too small to be regarded as statistically significant. If in longer series of cosmic-ray data from high latitudes a periodic 27-day wave should be definitely established, this would confirm the much disputed existence of a solar magnetic moment. The absence of any such wave would indicate either that the solar magnetic moment is parallel to the Sun's axis of rotation or that the magnitude of the moment is too small to produce an effect detectable in the available data.

On the variability of the 24-hour waves in cosmic-ray intensity. Preliminary examination of the variability in the 24-hour waves in cosmic-ray intensity and in magnetic horizontal intensity for about 100 individual days at Huancayo gave no indication of association between the two. This partial test thus furnished no evidence in support of theories advanced by R. Gunn and by M. S. Vallarta and C. Godart, that the 24-hour wave in cosmic-ray intensity arises, wholly or in part, from the 24-hour wave in magnetic horizontal intensity.

A comparison of the variability in the 24-hour solar wave in cosmic-ray intensity at Cheltenham and at Godhavn gives indication of definite association. If this is substantiated by further comparison at other stations for longer intervals, it will provide valuable material for testing theories for the cause of the diurnal variation in cosmic-ray intensity.

On the possibility of a lunar magnetic field. Utilizing the results of harmonic analyses of cosmic-ray data at Huancayo for single days throughout an entire year, a preliminary search gave no indication of a 24-hour lunar wave in cosmic-ray intensity. Such a wave would result from a lunar magnetic field of sufficient magnitude.

On the 12-hour sidereal wave in cosmic-ray intensity. Using the same data as for the above lunar investigation, a preliminary search gave no indication of a significant 12-hour sidereal wave in cosmic-ray intensity at Huancayo. The existence of such a wave would provide important evidence on the source of cosmic rays.

STUDIES OF COSMIC RAYS

THOMAS H. JOHNSON¹

The east-west symmetry of the soft component. The additional funds made

¹ Bartol Research Foundation of the Franklin Institute, Swarthmore, Pennsylvania.

available by the Carnegie Institution for the continuation of our high-altitude studies made it possible to carry out some studies of the asymmetry of the cosmic-ray intensity at very high altitudes near the equator. These studies had the specific purpose of learning what type of primary radiation is producing the meson rays of the hard component in the upper atmosphere. It was already realized that the mesons were being produced there as secondaries by some other form of primary particles whose electric charges were almost entirely positive (see report in Year Book No. 37 [1937-1938]). There was also strong evidence that the primary particles of the soft component were electrons. If, then, it could be shown that the electrons were almost entirely positive, from a study of their asymmetry, then it would be reasonable to assume that the mesons were being produced by electrons. On the other hand, if the electrons were not asymmetric and were therefore equally divided between positive and negative, one would have to conclude that mesons were not produced by electrons, but by some other form of radiation, most probably protons. In view of the important rôle played by the meson in modern theories of the nucleus, any light which could be thrown, in this way, upon the proton-meson production process would be a significant advance in nuclear physics as well as in our understanding of the cosmic radiation.

During the month of January 1939, eleven flights were released from the Barro Colorado Island Laboratory in the Panama Canal Zone. These carried triple-coincidence Geiger-Müller counter-apparatus for recording the cosmic-ray intensity at a zenith-angle of 60° , a radio transmitter for recording the data at the ground-station, and an arrangement which produced a slow but steady rotation of the instrument as it ascended. A photocell directional indicator, acted

upon by the rays from the Sun, made it possible to compare directly the intensities from the eastern and western halves of the sky. Four of these flights gave completely satisfactory records up to elevations in excess of 70,000 feet. On two other flights the cosmic-ray data were exceptionally good but the orientation signals failed. However, these two flights provided us with data which have been analyzed to see if any fluctuations were present which might have been introduced by the rotation of the balloon if the radiation were asymmetric. All these flights have shown that there is but a slight asymmetry, much less than would have been expected if the primary electrons of the soft component were as predominantly positive as the primaries of the hard component. An analysis of our results shows that less than a 10 per cent excess of intensity produced by positive primaries is present in the stratosphere and this could be accounted for almost entirely by the hard component, and that the numbers of positive and negative primary electrons are almost exactly equal. This means, then, that the mesons of the hard component are not produced by electrons but by some other type of positive particle, most probably protons.

Vertical intensity as a function of elevation and the distribution of intensity at high elevations with respect to zenith-angle. One of the important tests of the electron theory of the soft component is the comparison of the calculated and experimental curves representing the variation of vertical intensity with depth in the atmosphere. Here the assumption is usually made that the intensity from any direction is a function of the amount of matter through which the radiation has had to pass along a straight path at that angle. With the unidirectional coincidence-recorders which we have been using it is possible to test this assumption, and

we have compared the intensities along equal paths in the vertical and at a zenith-angle of 60° in some flights at the equator. Our preliminary results indicate that the fundamental assumption is not correct, but before making a final statement in this matter it will be necessary to make further studies of the effect. Funds for this purpose have been appropriated by the Institution and the work is progressing.

Development of technique for balloon studies. In addition to the developments reported last year, which included an improved radiobarograph and a number of circuits for recording and scaling down the number of impulses from a Geiger counter, we have now developed a high-voltage source suitable for operation of Geiger counters in these balloon flights which eliminates about half of the cost and weight of our batteries. This source, based upon a suggestion of Huntoon, operates on the induction-coil principle with the vibrator replaced by an oscillating vacuum-tube circuit. An important feature is an automatic control against voltage-variations produced by variations in the load, variations in the plate-battery, or variations in the filament-voltages. In all respects this device is as good as the batteries we have formerly used and it eliminates many of the defects of the latter.

Experiments on the stability of the meson. Recent experiments have shown that the intensity in the hard component of the cosmic radiation depends upon two factors, the amount of matter traversed by the rays and the time required for the rays to reach the detecting apparatus from the point at which they were produced. The importance of the time-factor has been interpreted as an indication of the instability of the meson, and it has been suggested that these particles disintegrate as in ordinary radioactivity. The mean life of the meson can be measured by comparing the num-

bers of cosmic rays arriving along two paths differing as regards the time required for their traversal but being equal as regards the total stopping power of the matter traversed. In our experiments we have used a vertical path through a tank of water and through the atmosphere for which the equivalent stopping power was 1.89 atmospheres, and an inclined path through the atmosphere with an equal stopping power, but a longer time. We are also using a vertical path in lead containing an equivalent stopping power of 1.5 atmospheres and are comparing the intensity on this path with that along an inclined path with an equal stopping power of air. Preliminary values of the mean life of the meson have been found of the order of 2 or 3 microseconds. These studies are being continued.

Calculation of the angular dispersion of low-energy cosmic rays by the Earth's magnetic field in the upper atmosphere. When secondary cosmic rays are produced with a low energy or when initially energetic cosmic rays have lost most of their energy, they may be acted upon by the magnetic field and bent out of their straight-line path, producing a diffuse beam in which the particles are not aligned with the primaries which produce them. This effect has been calculated and has been found to be insufficient to have an important bearing upon our asymmetry-measurements at high altitudes or upon the zenith-angle measurements referred to above.

A summary of cosmic-ray investigations. With the assistance provided by grants from the Carnegie Institution it has been possible to devote some time to the publication of a summary of investigations of the cosmic radiation. This appeared in the *Reviews of Modern Physics*, October 1938, under the title "The cosmic-ray intensity and geomagnetic effects."

Personnel. Since August 1938 the

writer has been assisted by Dr. J. Griffith Barry, who has been devoting his entire time to the balloon program. Mr. M. A. Pomerantz has been assisting with the experiments relative to meson instability. Our work at the Barro Colorado Island Laboratory was greatly facilitated by the generous cooperation of Mr. James Zetek and Colonel S. B. Akin of the U. S. A. Signal Corps. The writer wishes also to acknowledge the cooperation of the Panama Railroad S. S. Line, which allowed a liberal discount in transportation to the Canal Zone.

COSMIC-RAY INVESTIGATIONS

S. A. KORFF¹

The following studies have been pursued between July 1, 1938 and June 30, 1939, in connection with the cosmic-ray investigations with the aid of funds allotted by the Carnegie Corporation through the Carnegie Institution of Washington. The observations have been made using the recently developed technique of transmitting data by short-wave radio from instruments carried aloft by small balloons.

Single Geiger-Counter Measurements

Absence of effects due to solar flare. On July 27, 1938, a radio balloon flight was made, in which the scaled counting rate of a single Geiger counter was transmitted. This was the first flight to employ a new arrangement for automatically releasing the fabric of balloons which had burst, and which made it possible to calculate in advance the inflations required to cause a flight to level off after a predetermined number of balloons had exploded. The flight leveled off at 66,000 feet and remained there for about 7 hours. During this time an intense solar flare took place, accompanied by a radio fade-out. No

increase in counting rate was observed, as large as the experimental error of 2 per cent, coincident with the flare. Hence it is concluded that no ionizing radiation originating in the flare penetrated to the depth at which the instrument was floating. However, the fact that a radio fade-out was produced indicates that abundant ionizing radiation has reached a somewhat higher altitude. These two conditions permit upper and lower limits to be set to the absorption-coefficients of the radiation. These limits were 0.1 and 25 per gram; it was further shown that if the radiation were of the nature of X-rays, the wave-length must lie between 0.1 and 1.5 Ångstrom units.

Diurnal effect at high elevations. Flights were made during the day and during the night with counters whose counting rates had been standardized with a radium source previous to the flight. It was shown that no diurnal effect as large as the experimental uncertainty of 3 per cent exists at any altitude reached in these flights (up to 80,000 feet). The observations at night were about 1.5 per cent lower than those in the daytime at the highest altitudes reached, but this cannot be regarded as established with certainty. Nevertheless the order of magnitude of this effect is in agreement with the calculations made by Vallarta, on the assumptions (1) that no penetrating radiation originates in the Sun and (2) that the Sun may have a magnetic field sufficient to influence the softer components of the primary radiation.

Comparison of Counter- and Electro-scope-Measurements

Inasmuch as counters count numbers of ionizing events regardless of the amount of ionization accompanying each, and electroscopes measure the integrated total of ionization along the tracks of each ray passing through them, a comparison of counter- and electro-

¹ Bartol Research Foundation of the Franklin Institute, Swarthmore, Pennsylvania.

scope-measurements at various altitudes permits evaluation of the relative amounts of ionization accompanying each ionizing event at the various altitudes. By comparing the electroscopemeasurements made by Millikan and his collaborators with the Geiger-counter measurements described above, it was shown that the radiation is, on the average, 1.1 times as ionizing per event at a high altitude (0.75 meter of water equivalent below the top of the atmosphere) as at a lower elevation (4 meters of water). This effect may be attributed to (a) the simultaneous passage of multiple cascade particles through the instrument, and (b) heavy particles of high specific ionization, both of which processes are more probable at the higher elevations. That the effect is not larger than stated shows that the bulk of the ionization at high elevations is produced by single particles which ionize like electrons.

Neutron-Measurements

Development of special counters. The conditions necessary for the operation of proportional counters with stable characteristics and absence of critical dependence on potentials were investigated. It was found that certain filling gases, notably carbon tetrachloride and boron trifluoride, gave counters the property of producing large subthreshold pulses over wide voltage-ranges. It was thus found possible to construct a counter in which the size of the pulse was proportional to the amount of ionization produced in the counter by the passage of the ionizing particle. With these counters it is possible to discriminate between alpha and beta rays over voltage-ranges of several hundred volts. The discharge in these counters is internally quenched and hence no high quenching resistance or equivalent vacuum-tube circuit is necessary. Exceptionally high counting rates can

therefore be obtained, and the counter does not paralyze while discharging one million times per second. The boron trifluoride counters are suitable for detecting neutrons, since a neutron produces an alpha particle by interaction with the boron nucleus and this alpha particle may then be detected by the proportional counting method described. The neutron-boron reaction is most probable for slow neutrons, but it was shown that it had a usable probability for neutrons of energy up to 10,000 volts. It was further shown that these counters measure the neutron-density (the number of neutrons per cubic centimeter) independently of the energy up to the limit cited. Neutrons of greater energy are also counted, inasmuch as they produce recoil nuclei in the counter. In this case, however, the quantity measured is the neutron-current (number of neutrons crossing a square centimeter of surface per second) and not the neutron-density.

Balloon flights with neutron-counters. Using the neutron-counters described, a series of flights was made, in which the neutron-intensity was transmitted by radio from the instrument carried by balloons. The special amplifier-circuit for this work was developed and tested, and was built in the light form necessary for balloon work. It was found that the counting rate due to neutrons increased rapidly with altitude. The rate of increase with elevation at low altitudes was faster than that of the cosmic radiation, while at higher levels it was about the same as that of the total cosmic-ray intensity. The neutron-intensity in the upper atmosphere was found to be about a thousand times as great as at sea-level. At these high elevations, the neutrons are almost as abundant as the charged ionizing particles. Since, however, the neutrons produce very little ionization, their presence could not be directly detected by the

usual ionization-measurements and had hitherto been inferred from recoil tracks in photographic emulsions. The abundance of the neutrons indicates that nuclear disintegrations are frequently induced by the cosmic radiation. The neutron-density varied with elevation at about the same rate as the number of photons of energy greater than about five hundred million volts. This suggests that neutrons are evaporated out of nitrogen nuclei in the upper atmosphere by the energetic photons associated with the cosmic radiation. The production cross-section for this process has been calculated from the data, and is found to be of nuclear dimensions, as might reasonably be expected. No other process has as yet been advanced for which the production cross-sections are not larger than nuclear dimensions. The further consequences of this process are at present being investigated.

A preliminary flight has also been made, employing a proportional counter not sensitive to slow neutrons. This flight serves (a) as a control experiment on the neutron flights and (b) as enabling an upper limit to be set to the number of fast neutrons producing recoil nuclei in the counter, to the number of protons between 10^8 and 10^9 volts, and to the number of nuclear disintegration-processes. The connection between neutrons and bursts is also being investigated at sea-level.

Parts of this program have been carried out in active cooperation with T. H. Johnson. Thanks are also due W. F. G. Swann, C. G. Montgomery, and E. T. Clarke for helpful advice and assistance.

ESTABLISHMENT OF A COSMIC-RAY
OBSERVATORY AT GODHAVN,
GREENLAND

VIGGO LAURSEN¹

During 1936 Dr. J. A. Fleming, Director of the Department of Terrestrial

Magnetism of the Carnegie Institution of Washington, expressed the hope that the world net of cosmic-ray observatories established by the Institution's Committee on Coordination of Cosmic-Ray Investigations might be extended with an observatory at Godhavn, Greenland, where it could be operated in connection with the existing magnetic observatory. Dr. D. la Cour, Director of the Danish Meteorological Institute at Copenhagen, responsible for the scientific work of the Godhavn Observatory, cooperated in this effort and obtained a grant from the Danish Government to assist in the establishment of the station.

A cosmic-ray meter was delivered in Copenhagen in May 1938 and was shipped on the Government vessel *Disko*, together with building materials for the observatory, early in June. H. P. Barfod, assisting observer at the Observatory, and Viggo Laursen, on furlough from the Meteorological Institute, went to Godhavn to assist Director K. Thiesen of the Observatory in the erection of the cosmic-ray hut and installation of the apparatus. The party arrived at Godhavn June 23, 1938. The building was begun early in July. The building consists of a ground floor (afterward made underground by burying it in a small hill of earth) for the heating arrangements and an upper floor for the installation of the meter. It is on a rocky slope about 25 meters east of the dwelling house of the Observatory. The ground floor is of concrete. Three ventilating holes in its ceiling permit warm air to pass into the instrument room, and a fourth and larger hole over a return-air funnel insures return of the cooled air from the upper floor to the heating room. Heating is supplied by a large brick stove using Greenland coal, with suitable damper adjustments at the three openings in the ceiling. The plan is to maintain the temperature throughout the year at about 15° C, which is about the

¹ Danish Meteorological Institute, Copenhagen, Denmark.

highest outside temperature during the summer.

The upper floor is of well-insulated wooden construction. The walls, from outside to inside, are composed of: (1) 1-inch sheathing, (2) tarred paper, (3) celotex, (4) air space between studding, (5) celotex, (6) four layers of 25-mm rock-wool mats, (7) 1-inch sheathing, (8) hard masonite. The ceiling consists of a layer of 1-inch boards with hard masonite on the under side and covered with four layers of 25-mm rock-wool mats. The board roof is covered with two layers of roofing paper.

The entry to the instrument room is 2.6 by 1.3 meters and the instrument room itself is 2.6 by 1.8 meters. The concrete floor of these two rooms is covered with a layer of hard masonite. Despite highly unfavorable weather conditions with much rain, the building was completed on September 22, 1938.

The installation of the cosmic-ray meter was then made in accordance with the instructions. Considerable difficulty was experienced in the adjusting of the uranium rod because its square head was twisted off in the attempt to make this adjustment. It was necessary therefore to drill and scrape a solid notch in the end of the rod so that it could be turned readily by a special screwdriver. The first tests of the meter were made early in October. Following necessary adjustments of the optical parts, registrations have been continuous since October 6, 1938. Records of atmospheric pressure are checked with daily readings of a standard mercury barometer placed in the instrument room. A Fuess thermograph controlled by daily readings of a thermometer records temperature in the instrument room, while a second Fuess thermograph records the outside temperature in a near-by meteorological shelter.

The Observatory is in latitude $69^{\circ} 14'4$ north (geomagnetic latitude $79^{\circ}9$

north) and longitude $53^{\circ} 31'3$ west (magnetic longitude $32^{\circ}5$ west). The height of the cosmic-ray meter above sea-level is 9 meters. The highest point in the horizon is a basalt mountain range toward the north rising to about 14° above the horizon in the so-called Lyngmarksfjeld.

STUDIES OF COSMIC RAYS

ROBERT A. MILLIKAN¹

The researches which have been pursued and the results obtained between July 1, 1938 and June 30, 1939 in the cosmic-ray studies carried on at the California Institute of Technology, with the aid of funds supplied by the Carnegie Corporation of New York and administered by the Carnegie Institution of Washington, may be very briefly summarized as follows:

Measurement of atmospheric temperature-effects at sea-level. Millikan and Neher in studying sea-level seasonal effects have sent one of their self-recording electroscopes, encased in a 10-cm lead shield, repeatedly on a slow Norwegian steamer over the route Vancouver-Los Angeles, around South America, and return to Los Angeles and Vancouver, and have found the following results:

1. As heretofore, an equatorial dip, measured from Los Angeles, of 7 per cent on the western side of South America, 8 per cent on the eastern side.

2. No seasonal sea-level effect at Los Angeles or at any point south of there down to the Straits of Magellan that is of sufficient magnitude to stand out above the fluctuations—as much as 0.6 per cent—observable at the different localities traversed in these voyages.

3. As heretofore on the voyage between Los Angeles and Vancouver, constancy in cosmic-ray intensity in summer

¹ California Institute of Technology, Pasadena, California.

and fall, within the limits of uncertainty imposed by the fluctuations, estimated here as certainly not over 1 per cent.

4. In winter and spring, however, a definite increase in different voyages of 2 or 3 per cent in going from Los Angeles to Vancouver.

The results found in (3) and (4) above are interpreted as still further definite evidence for the existence of the "atmospheric-temperature" effect earlier studied by Hess,² Compton,³ and Forbush,⁴ and their respective collaborators.

Measurement of the total cosmic-ray energy entering the atmosphere at different latitudes. Millikan and Neher in late June and early July 1938 sent their self-recording electrosopes on four successful balloon flights reaching 98 per cent of the way to the top of the atmosphere at Bismarck, North Dakota (magnetic latitude 56° north), and two weeks later on three such flights at Oklahoma City (magnetic latitude 45° north). Also, six months later, namely, in December 1938, they made four similar flights at Omaha. Comparison of the results of these flights showed the following: .

1. The lowest energy at which cosmic-ray electrons enter the Earth's atmosphere at all corresponds closely to the energy required to get through the Earth's magnetic field vertically at Bismarck, namely, about two billion electron-volts.

2. At this critical latitude larger fluctuations (4 or 5 per cent) appear in successive flights taken a few days apart than were brought to light in working at latitudes farther south.

3. The electronic energy entering the Earth appears to possess two maxima, one at two billion electron-volts and one at about six billion electron-volts. If

later more complete measurements now being made in quick succession in a series of different latitudes confirm this result, it will have an important bearing upon the as yet unsolved mystery of the origin of the cosmic rays.

4. The total or integrated incoming cosmic-ray energy found at Omaha in winter (1938-1939) was nearly 10 per cent greater than the energy entering at that same point in the summer of 1937. This 10 per cent of change cannot be an "atmospheric-temperature" effect of the kind found in (4) above, and interpreted by Blackett in terms of meson decay-time. It is too large and takes place too high up in the atmosphere to be so interpreted. It constitutes instead *new evidence for a considerable variability in the intensity of the cosmic-ray electrons entering the top of the atmosphere.* Qualitatively this variability is in line with that appearing in Forbush's⁵ discussion of the records of the cosmic-ray meters kept running by the Carnegie Institution of Washington at Cheltenham (50°1 north, magnetic latitude), at Teoloyucan (29°7 north), at Christchurch (48° south), and at Huanacayo (0°65 south).

Development of new very high-speed Geiger-Müller counters. Neher and Pickering have this year developed a practical technique for producing very fast counter-tubes, both large and small. These counters are permanent, reliable, and have a "plateau" at least as long as 30 per cent of their threshold voltage. Times of reaction indicate that in these "fast" counters the charges are collected in about one one-thousandth of the time necessary in the ordinary "slow" counter, and this in turn indicates that the agents entering into the breakdown are largely electrons. The following specific results have been obtained:

1. The measured reaction times are but 10⁻⁸ second, or even better. It has

¹ Wiener Ber., IIa, vol. 143, p. 313 (1934); vol. 144, p. 53 (1935).

² Phys. Rev., vol. 52, p. 799 (1937).

⁴ Phys. Rev., vol. 54, p. 975 (1938).

⁵ Phys. Rev., vol. 54, p. 975 (1938).

been found necessary to use only *double coincidence* in a balloon flight to measure directional effects. An efficiency of 100 per cent has been obtained in the use of these counters for measuring by the radiometerograph principle the intensity of cosmic rays in very high-altitude sounding-balloon flights. With these tubes the number of accidentals is at all times negligible.

2. Using these "double-coincidence" counters in preliminary flights at Pasadena, data have been obtained on the *vertical* intensity of cosmic rays up to 0.75 equivalent meter of water from the top of the atmosphere. The probable error of a single 4-minute average at the maximum of the curve is only 1.6 per cent figured from the number of counts. This accuracy is much better than has been reported by other observers using the counter-method.

3. Also, flights in which radio reception is used are now being made with *single* large counters to measure the total cosmic-ray intensity to compare with and eventually perhaps to take the place of electroscopes. Attempts are also being made to secure data on the west excess of cosmic rays at high altitudes with counters inclined to the vertical.

Cloud-chamber measurements on the energies, the absorption, and the scattering of cosmic rays. 1. Anderson and Neddermeyer have made determinations of the number and the distribution in energy of the secondary negative electrons produced in metal plates by the passage of high-energy penetrating particles (mesons). As regards both number and energy-distribution the results agree well with theoretical expectations. Measurements from two sets of data (4500 particle-traversals through 0.35-cm lead plate and 2700 particle-traversals through 1-cm platinum plate) were reported at the Chicago symposium in June 1939, and are now in press.

2. Anderson, Neddermeyer, and Kuo

have made measurements of the energy-loss of the low-energy cosmic-ray particles ($E < 500$ mev) in plates of carbon. In an element as light as carbon practically the whole energy-loss is by direct ionization, radiative losses disappearing with the light elements on account of the Z^2 law, and since all the mass-estimates of the meson so far made have assumed the validity of the theoretical laws of direct ionization, a direct experimental test of these laws is vital. These experiments, which are statistical and can make use of only about 1 per cent of the particles photographed, are as yet incomplete. Preliminary data based on 5000 photographs show approximate agreement with theory as regards average energy-loss through direct ionization. In these experiments small thin-walled Geiger counters placed inside the chamber were used in coincidence. Dr. J. K. Boggild developed suitable counters of only 0.005-inch copper total wall-thickness.

3. Anderson and Vargus have made experiments on the multiple scattering of cosmic-ray particles in platinum and have found approximate agreement with the scattering to be expected theoretically. A report of these results is in press.

4. Anderson and Neddermeyer have succeeded in obtaining excellent tracks with a large expansion-chamber designed to improve the accuracy of energy-measurements. The inside diameter of this chamber is 85 cm, and so far it has been operated only without a magnetic field. Experience with this chamber has shown that chambers of this size can be made to operate very satisfactorily. By employing light scattered at about 30° instead of the customary 90° for the track-photography, the light can be used some 100 times as efficiently, and usual light-sources are found perfectly adequate for the illumination of so large a chamber.

COMMITTEE ON STUDY OF THE SURFACE FEATURES OF THE MOON. *Progress report for the period July 1938 to June 1939.* (For previous reports see Year Books Nos. 26-37.)

The surface of the moon presents an interesting field for study; its distance, however, is so great that the attainable results must ever remain comparable to those of rough reconnaissance on the earth. Topographic maps of the moon's surface are lacking and detailed study of the shapes and dimensions of its individual features has still to be made. The scale of existing lunar maps rarely exceeds 1:5,000,000; their chief purpose is to aid the observer in locating different surface features that have been named; of these, the selenographic positions of approximately 4000 have been accurately measured by Saunder and by Franz and referred to the plane of mean libration. In comparison with good terrestrial maps, lunar maps leave much to be desired; this situation is likely to persist, because the average distance to the moon is nearly 240,000 miles. It can be improved only by the development of new methods of attack and more accurate data of measurement.

One of the first tasks of the geologist on entering an unexplored area is to ascertain the nature of the surface rocks and of their relations one to another; also to note the climatic and other conditions to which they are exposed and their behavior under these conditions. At the same time a field map is prepared to aid in the location of the different features and in the plotting of the geological formations.

A similar course is followed in the investigation of the moon's surface. Unfortunately, the moon cannot be visited and the student of its surface must ascertain the nature of its surface materials by their effects upon sun's rays on reflection, scattering, and radiation in the direction toward the earth. He is also forced to prepare maps with the aid of photography and study of the slope angles of its features.

During the past year special effort has been made to obtain a series of lunar photographs suitable for use in connection with the method of grazing incidence for ascertaining the slope angles of certain lunar formations. The Committee was fortunate in having use of the 100-inch telescope during the lunation of July 1938. During this period more than 400 photographs of the moon were taken at the Newtonian focus, at which the disturbing effects of coma were reduced by means of the new three-element zero corrector lens designed by F. E. Ross. Seeing conditions during the month of July were relatively poor; on thirteen nights the seeing was 1 or less on a scale of 10, in which 10 signifies perfect seeing; as a result many of the negatives are only fair in quality. They are, however, adequate for the determination of slope angles by the method described in the report of last year.

Several hundred enlargements from selected negatives of this series were made that show the moon at different phases and with a diameter of 15 inches (scale 1:9,123,800). These enlargements were studied by Miss Helen Wright of the Department of Astronomy of Vassar College with the aid of accurate projection charts, and the slope angles of many crater walls were ascertained. By use of perspective projection plots it is possible to measure directly on a photograph the linear dimensions of a crater and also the angle of elevation or altitude of the sun at that point at the time the exposure was made. This method is similar in principle to the length-of-shadow method, but it is much more rapid and enables the observer to follow the change in slope angle of any given lunar feature as its slopes are ascended from photograph to photograph; in other words, to prepare a topographic map of the feature. The routine work on the

surface features has still to be done, but the method has been thoroughly tested and its feasibility proved.

On small craters, a mile or two in diameter, the angle of the inner slopes may reach 55° ; this angle is surprisingly large, if the materials are of the nature of volcanic ashes and pumice. The problem of the limiting angle of repose of loose materials on the moon's surface, at which gravity is one-sixth of that of the earth and no water or air is present, is being attacked by Dr. P. S. Epstein of the Moon Committee. The slope angles of larger craters are much smaller; many of their walls are terraced.

A number of stereoscopic pairs of lunar photographs have been chosen from the series of negatives for examination with a special stereoscope. Experience has shown that stereoscopic views of the moon enable the observer to see details that escape attention in a single print. Further study by this method is in progress.

The report on the results obtained by visual measurements of the percentage polarization of light from terrestrial materials and from certain parts of the moon's surface at different lunar phases is in course of preparation and should be completed during the coming year.

Much time has been spent in testing and developing the two photoelectric cell methods for the measurement of the percentage polarization of light scattered by terrestrial and lunar surface materials. In the direct-current method, the total intensity of light transmitted by an analyzing prism whose plane of vibration is parallel with the terminator is first measured, and then the intensity of that vibrating normal thereto. The ratio of the difference between the two intensities to their sum measures the percentage polarization in the incoming beam. Experience has shown that in this arrangement it is essential that exactly the same part of the sensitive photoelectric cell surface be used for all meas-

urements and that the impinging rays be normally incident on this surface. For these reasons a Glan-Thompson prism has been substituted for the quartz Wollaston prism, the amplifying circuit has been changed, and the apparatus rebuilt. It may be necessary to depolarize the light after passage through the analyzer in order to avoid the change in response of the photoelectric cell with change in azimuth of the plane of vibration of the incident light. The direct current might easily be converted into a null method by use of a tilting plane-parallel plate, as in the visual eyepiece; but it has seemed wise first to test the direct method thoroughly and to keep it as different from the visual method as possible.

The alternating-current method has also been under test, and certain mechanical defects have been found that must be corrected before satisfactory tests can be made with the apparatus. The circuit has been changed in certain respects to improve its characteristics. The method promises to be extremely sensitive for low percentages of polarization. The difficulty with change in sensitivity of the photoelectric cell surface from point to point and with change in azimuth of the plane of vibration of the incident rays still remains, as in the direct-current method, and the same precautions have to be taken to overcome it. Similarly, this method can be converted into a null method by use of the plane-parallel plate so placed that it is in front of the rotating analyzer and has its axis of rotation parallel with the plane of vibration of the polarized component of the incoming beam.

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JOSEPH C. BOYCE, *Massachusetts Institute of Technology, Cambridge, Massachusetts.*
Research in the spectroscopy of the vacuum ultraviolet.

The present investigation is a natural continuation of the program carried out by Dr. K. T. Compton as a Research Associate of the Carnegie Institution of Washington, and is being conducted under a grant from the Carnegie Corporation of New York through the Institution. (See Year Books Nos. 28-34.) The vacuum spectrograph designed and built by Dr. Compton has remained in use in this laboratory. Until lately the time required for the measurement and reduction of plates has so greatly exceeded the time consumed in making the exposures that the spectrograph itself has been in operation only a small fraction of the time. The recent development by Professor G. R. Harrison, in this laboratory, of equipment for the automatic measurement and reduction of spectrum plates has made possible a considerable speeding up of the program. In one of the earlier reports (Year Book No. 33 [1933-1934]) Dr. Compton mentioned a particular exposure which required 80 hours of measurement and 60 hours of computation to obtain approximate wave lengths, apart from final correction of these wave lengths by a correction curve obtained from the wave-length standards. Using the new automatic comparator, one obtains the same result in less than an hour. The records of the automatic comparator include as well a complete microphotometer trace of the spectrum under investigation.

Professor Harrison is now engaged in a remeasurement of the line spectra of all the elements over a wave-length range from $\lambda 2000$ in the ultraviolet to $\lambda 10,000$ in the infrared. The present program is designed to supplement his by extending the spectra farther into the ultraviolet, in the first step from $\lambda 2000$ to $\lambda 1200$ and then in the second step from $\lambda 1200$ to $\lambda 400$. At the time of writing

this report, the present program has been in progress for only seven months. Considerable experimentation has been required to develop methods suitable for the very extensive program, but by the late spring methods had been developed so that the spectra of three or four elements could be recorded per week over the $\lambda 2000$ to $\lambda 1200$ range.

After excellent spectra, with adequate wave-length standards, had been obtained for ten elements and preliminary spectra for ten additional elements, tests were initiated on the measurement of the spectra. The dispersion of the Carnegie vacuum spectrograph differs from that of the other instruments of the laboratory. This fact required an alteration of the gear ratio, or of the dials, of the automatic comparator. Professor Harrison kindly cooperated in making the necessary changes, and a series of tests has shown that the new arrangement (of the dials) of the machine functions very reliably. Automatic measurements have now been obtained for the best exposure (with standards) spectrum of each of ten elements. At the moment tabulation methods are being organized so that the wave lengths may be transcribed and final corrections applied by the very careful, but necessarily uncritical, members of the WPA staff who are assisting in the program. As soon as this clerical part of the program has been found to run smoothly, operation of the spectrograph will be resumed and the various stages of the program will go forward simultaneously.

Professor Wulff, of the Metallurgy Department, has given considerable assistance in the preparation of compressed powder electrodes. This makes possible spark sources for many elements that would be difficult to handle by the ordinary method.

At a later stage in the program it will be necessary to use a hollow cathode gas discharge as the light source. For certain spectra this source operates best in a constant current circuit. In another laboratory a monocyclic network circuit has been used very successfully to provide the constant current. Such a circuit is rather expensive to build. Preliminary experiments have been made on a simpler and somewhat less expensive circuit, using thyratrons, to achieve the same result. Equipment for these preliminary experiments was temporarily borrowed from the Electrical Engineering Department, only to test the principle of the circuit.

At a time of international tension it is satisfactory to report that photographic plates sensitive to the vacuum ultraviolet are now being manufactured in this country. Until this last year we were dependent on either of two manufacturers of plates in England, and the thin glass on which the emulsion was coated came from either Belgium or Germany. The new domestic supply is very much cheaper than the imported plates, because it is merely a standard photographic emulsion coated with a fluorescent substance. Both types of imported plates had special emulsions.

A critical bibliography of published spectra in the vacuum ultraviolet has been prepared and will be included in an article on spectroscopy of the vacuum ultraviolet now in preparation for the *Reviews of Modern Physics*. On the basis of this bibliography a card catalogue has been prepared of the published wave lengths. It will be useful in checking the identifications of lines measured in the present program. The WPA staff has given much assistance in the preparation of the catalogue.

In the coming year priority will be given to the measurement of the vacuum ultraviolet spectra of elements under

investigation in this laboratory or in cooperating institutions. Beyond that, emphasis will be placed on obtaining a library of plates of the spectra of as many other elements as possible, over the range from $\lambda 2000$ to $\lambda 1200$. After about a year from now, if the program is continued, it should be possible to commence work on the shorter wave-length region, from $\lambda 1200$ to $\lambda 900$.

No material from the present program is yet ready for publication. A list is appended of papers published since Dr. Compton's last report (Year Book No. 34 [1934-1935]) using data obtained with the Carnegie spectrograph.

Dr. Lore Misch, formerly of Göttingen and more recently of the Institute of Chemistry of the University of Geneva, has been employed as a research assistant under the grant. She has operated the spectrograph and has very effectively cooperated in other parts of the program. Temporary assistants have been employed for work on the constant current circuit and for clerical work on the bibliography. Miss Dorothea Baker assisted in the preparation of the wave-length catalogue, working for six weeks as a volunteer assistant.

PAPERS PUBLISHED SINCE DR. K. T. COMPTON'S
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DATA OBTAINED WITH CARNEGIE VACUUM
SPECTROGRAPH

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*Investigations in cooperating laboratories based in part on data obtained with the Carnegie vacuum spectrograph at the Massachusetts Institute of Technology.

P. S. EPSTEIN and G. W. POTAPENKO, California Institute of Technology, Pasadena, California. *Study of influence of the earth curvature on the propagation of short electromagnetic waves.* (For previous report see Year Book No. 37.)

The grant made by the Carnegie Corporation of New York and administered by the Carnegie Institution of Washington for the study of the reception of micro radio waves has been used for quantitative study of the propagation of short and ultra-short radio waves over the surface of the earth. The program carried out during the past year is as follows:

The equipment for sending and receiving waves of 5 meters wave length has been subjected to tests. The transmitter was installed on the shore of the Pacific on the terrace of the California Institute Marine Laboratory at Corona

del Mar, and the receiver was mounted on a power boat. The tests proved this equipment to be entirely satisfactory. The measurements could be made sufficiently precise at distances several times larger than the distance of direct vision.

An analogous equipment for waves of 1 meter wave length was completed, consisting of a power plant, a transmitter, and a receiver.

Preliminary tests with the 1-meter equipment carried out on the Salt Flats of Utah showed an accuracy somewhat short of that desired. Work to improve the accuracy is now in progress.

PHYSIOLOGY

G. OSCAR RUSSELL, Ohio State University, Columbus, Ohio. *Research in the physiological cause of voice quality differences.* (For previous reports see Year Books Nos. 28-33, 35, 37.)

These studies have continued during the academic year 1938-1939.

Some lines of investigation laid down at the inception of this study have now been pursued far enough to see the end, and announce definite results. In dealing with an auditory problem of this kind which cannot always be demonstrated mathematically, but where the facts are nevertheless clearly perceivable by the auditor, the sound picture is sometimes a more effective means of publication than the printed page. This year a major part of the director's time was given therefore to summarizing our most basic experiments on the primary cause of voice quality distinctions; and to completing organization of these facts in a sound picture film. For, as stated in previous reports, the results of every objective experiment we could set up tended to disprove the previously held assumption concerning this point. It becomes therefore one of the most basic aspects of our major problem.

Our first presentation of this motion picture sound film summary of the evidence was made before the six weeks'

Symposium on Scientific Studies of the Voice held at Northwestern University this summer. It will next be presented as a part of our exhibit in New York museums; later in Baltimore, Chicago, and elsewhere. Copies will be made available to laryngologists, pathologists, physiologists, physicists, or other scientists, and to laboratories, teachers, and universities generally.

This film presents the experiments themselves. They seem to us to be conclusive demonstration of certain facts we feel we have now established, pertaining to the basic problem of "resonance" so-called, or carrying power in the voice. Each experiment makes an objective and apparently conclusive examination into one or more of the possible "resonance" effects which each of a series of conditions in the human head might supply.

These experiments point again to the sound source or vocal labia themselves as the main cause of so-called "resonance" or lack thereof; as the primary creative agency for both loudness and quality distinctions in the voice.

PSYCHOLOGY

HENRY A. RUGER, Teachers College, Columbia University, New York, New York.
Studies of correlational surfaces. (For previous reports see Year Books
Nos. 27-37.)

These studies have been continued with funds made available by the Carnegie Corporation of New York to the Carnegie Institution of Washington.

The task of completing the "transfer" of moments from arbitrary means to true means was completed for the five pairs of traits mentioned in the last report. There are thus now at hand 9 pairs of traits, for each of which 42 moments about the true means have been obtained. For each such pair of traits the moments and product moments are available both for the total population of 7000 males and for each of the 15 component age groups. These latter are for the 15 consecutive ages from 16 to 31. These sets of 16 values each, 1 for the total and 15 for the partial populations, are presented in tables and diagrams. This work is an extension of that for correlation and regression coefficients and correlation ratios published in the *Annals of Eugenics*, volume 5. Similar treatment is to be given to various func-

tions of the moments about true means. This has been concluded for the betas, functions of a single, here marginal, trait, which are important for curve fitting. The q 's bear a similar relation to surface fitting. They involve the ratio of the product moment coefficients to the product of the appropriate powers of the respective sigmas. The numerator of the Pearson r is the simplest product moment coefficient, and its ratio to the product of the two sigmas is the simplest q . Other functions as well as these are now being computed.

An average of fifteen statistical workers under the direction of E. K. von Brand, M.E., has been furnished by the Works Progress Administration. This service merits recognition for consistently devoted and efficient effort and accomplishment. Some of these workers are Daniel Shaw, office manager; Katherine Turner, Theodor Arkava, S. Brannan, J. Joachim, Nathan Weill, J. Pallis, and John Helmuth.

ST. AUGUSTINE HISTORICAL PROGRAM

VERNE E. CHATELAIN, St. Augustine, Florida. *The St. Augustine Historical Program*.
(For previous reports see Year Books Nos. 36, 37.)

Financial aid for support of these studies has been supplied in part from funds made available by the Carnegie Corporation of New York for the investigation of factors affecting the history of the United States.

The St. Augustine Historical Program completes its third year of research with the work of collecting and studying the great mass of written source materials proceeding steadily. Special attention has been given to the Lowery manuscripts in the Library of Congress, which now have been transcribed and translated in part for the files in St. Augustine. Another large collection of Spanish documents from the Archives of the Indies, translated during the current year, have been those in the custody of the North Carolina Historical Commission. This work was accomplished with the cooperation of the Commission and of the North Carolina Works Progress Administration. While these documents deal principally with the English and Second Spanish periods, they involve also a considerable amount of materials drawn from Spanish archives of the seventeenth century, especially the period from 1650 to 1670.

Commendable progress likewise has been made in the collection and preparation of data relating to historic houses and other sites in St. Augustine. This information has been plotted upon large-scale maps of the city, and arranged in such a way as to enable the student to see at a glance the changes which have occurred from time to time in the construction of buildings, and in ownership. Apart from their general historical value, these records are particularly important in helping to determine the merit of sug-

gestions in regard to proposed physical changes, which may be made during the course of the present Program.

Supplementary to the study of sites within the city are the archaeological and historical investigations relating to points along the old King's Highway south of St. Augustine. These include three counties of Florida—St. Johns, Flagler, and Volusia—and among the interesting sites examined have been several colonial plantations, sugar mills, military positions, and two possible Spanish missions. A wealth of information has been uncovered in this research, shedding light on rural conditions in Florida during the colonial period. In cooperation with county officials and officers and members of local historical societies, Mr. W. J. Winter, archaeologist, also has excavated, measured, and studied the foundations of the colonial fort on the Addison farm, which appears to relate primarily to the English period. An old stone building, partially restored at some earlier time, is one of the structural remains on this site. A complete set of the surveyor's plats and field notes of the first American surveys dealing with townships in these counties adjoining the King's Highway, as well as others of townships from St. Augustine northward to the mouth of the St. Johns River, have been added to the records of the Program.

Among the most important steps taken during the year in the study and preservation of house sites in St. Augustine has been the acquisition of the Llambias House, the funds for the purchase of which were generously provided by the Carnegie Corporation of New York and the St. Augustine Historical Society.

The arrangements to ensure the proper protection and development of this property, which is one of the few Spanish residences of the early eighteenth century remaining in the city, is another outstanding example of the fine spirit of cooperation marking the course of the Program from its very beginning. The legal title to the Llambias House was first given to Carnegie Institution of Washington, which in turn deeded the property to the city of St. Augustine, with the understanding that its management be placed in the hands of a Board of Trustees of six members, consisting of Mr. Waldo G. Leland, chairman; Mr. Frederic A. Delano, vice-chairman; Mr. David R. Dunham, treasurer; and Mrs. Francis King, Mr. William E. Lingelbach, and Mr. Newton B. Drury. Mr. Verne E. Chatelain, the Director of the St. Augustine Historical Program, was elected by the Board as its secretary at its first meeting, in Washington, D. C., on February 1, 1939.

The Board again met on March 22 in St. Augustine and made plans for a thorough architectural study of this historic structure. Two competent authorities in the field of historical architecture, Mr. Marion Sims Wyeth of Palm Beach, Florida, and Mr. John O'Neill of the Historic American Building Survey, Washington, D. C., accepted invitations to make examinations of the property, and their reports are now before the Board of Trustees for consideration. Accompanying Mr. O'Neill's study and recommendations also is a complete set of measured drawings of the house. Meanwhile the Board has approved an arrangement with the Federated Garden Clubs of St. Augustine, granting to that organization the privilege of using the Llambias House as its headquarters, and of developing, under the direction of the Board, a Spanish garden which in the course of time should add much to the interest in this historic site. Along with the architectural study, research in local

records is bringing to light additional information regarding the various stages in the history of the property.

A part of the year has been spent by Mr. Chatelain in preparing and revising the study on the defenses of Spanish Florida, to be published by Carnegie Institution of Washington. In this work he has been assisted by Miss Vera Smith, research assistant, who has also been engaged in transcribing and translating Spanish documents from collections contained in the Library of Congress. On March 28, Mr. Chatelain presented, in Elihu Root Hall, Carnegie Institution of Washington, the fourth in a series of public lectures arranged by the Institution, entitled "Contributions to American culture as illustrated in the early history of St. Augustine." It is expected that this paper, which has now been edited, in connection with an earlier study by Dr. John C. Merriam, President Emeritus of the Institution, dealing with the beginning of the St. Augustine Program and read in Philadelphia before the American Philosophical Society in 1937, will be published in the *Proceedings* of that Society. Other articles, bearing on military operations in Florida during the First Spanish and English periods, and on certain aspects of colonial trade, navigation, agriculture, and architecture, will appear in forthcoming issues of the *Florida Historical Quarterly*.

Finally, mention should be made of the cooperation given to Mr. E. W. Lawson, of the St. Augustine Historical Society, in the preparation of a one-volume study on the life of Ponce de Leon, now completed and awaiting publication; also to Mayor Walter B. Fraser, and to the Board of Trustees of the St. Augustine Historical Preservation and Restoration Association, in planning the steps to be taken in financing and in carrying forward the Program during the coming months.

SEISMOLOGY

CALIFORNIA INSTITUTE OF TECHNOLOGY. *Cooperative researches at the Seismological Laboratory, Pasadena, California.* (For previous report see Year Book No. 37.)

During the past year the staff of the Seismological Laboratory has continued to prosecute vigorously the researches for which the Laboratory was founded some thirteen years ago.

Registration of local earthquakes and study of the records, the first and very important purpose for which the seismological program was inaugurated, has continued to absorb a considerable fraction of the time and effort of the Laboratory group. Out of this unique and precise investigation flow results bearing on the nature and causation of earthquakes, on the relation of shocks to the structure and tectonic changes occurring in the region in which they originate, and on the directions and magnitudes of ground displacements during shocks, the latter information being of large value to engineers in design of earthquake-resistant structures, as more fully set forth in last year's report.

Another problem on which vigorous attack was continued is the constitution of the interior of the earth, evidence on which is derived from investigation of deep-focus earthquakes and from the velocities and manner of reflection and refraction of all types of earthquake waves in the earth's body.

Design and construction of new types of seismologic instruments, and improvement of types already in use, has continued. Advances in instrumental equipment are as essential in seismology and geophysics for the securing of new kinds of data as in physics or astronomy.

The Laboratory itself and the outlying stations at Mount Wilson, Riverside, La Jolla, Santa Barbara, and at Hai-

wee and Tinemaha in Owens Valley are in general in better operating condition than at any time in previous years, owing to improvement and replacements in recording and timing equipment.

Local earthquakes. The installation of Mercer chronometers at all of our southern California stations has greatly facilitated and shortened the process of determining precise time for the records and has consequently decreased the labor involved in the routine measuring; the accuracy has also been improved. The location, largely by Mr. Rogers, of the epicenters of many of the southern California shocks has consequently been more precise. The information included in the final reports on local shocks has therefore been more complete than heretofore. Many valuable data on earthquakes in the Southwest have been derived from seismographic records written at Tucson and kindly made available by the U. S. Coast and Geodetic Survey, and from records of instruments at Boulder City loaned by the U. S. Bureau of Reclamation.

In the southern California region no large shocks occurred during the year. Considerable seismic activity was manifested in surrounding areas. Several moderately strong shocks occurred to the northwest on the San Andreas fault in San Benito County. One of these, on June 24, 1939, caused minor damage to a number of weak structures. Activity continued near Boulder Dam, the shock of May 4, 1939 having been the largest thus far recorded from that area. To the east a considerable number of shocks

originated near the Arizona-New Mexico boundary between 33° and 34° north latitude; this series commenced September 17, 1938. Several moderately strong shocks occurred off the coast southwest of San Diego, of which those on May 1 and June 24, 1939 were the largest. Seismic activity continued in the Mojave Desert, and toward the end of 1938 increased activity was noted on the northern segment of the Inglewood fault west of Los Angeles, the fracture on which originated the destructive earthquakes of 1920 at Inglewood and 1933 at Long Beach.

On May 2, 1939, an earthquake of potentially destructive magnitude occurred at about 29.5° north latitude in the northern part of the Gulf of California, presumably on a southward extension of the San Andreas fault. Exceptionally high seismic activity affected the whole world during April and May 1939, but soon decreased again to normal.

A study was made by Dr. Richter of the location of epicenters in the southern part of the Pacific region of North America and their relation to the geologic structure. The results are to be presented in a paper at the Pacific Science Congress in Berkeley in August 1939. The zone of seismic activity of the Coast Ranges and Peninsular Ranges in California and Lower California was shown to fall directly in line with the principal belt of seismic activity which follows the entire Pacific coast of the continent.

On the map prepared to show the epicenters of all the larger shocks (magnitude 4 and over) for which precise instrumental locations are available in the southern California area, it is clear that during the ten years of more complete registration the epicenters do not outline the so-called major faults of the San Andreas type. Instead there is a relatively small number of active areas and the epicenters are located on var-

ious faults within these areas. Commonly the center of such an active area is crossed by a major fault. The deviation of the epicenters from the major faults is not due to instrumental error in determining the location of the epicenter. The deviation moreover indicates that it will be of great importance to continue the observation and cataloging of these shocks up to and past the occurrence of a major earthquake in the region, as such a series of observations on the distribution of seismic activity would cast much light on the mechanism of the development, accumulation, and release of regional strain and might possibly lead eventually to a carefully qualified type of prediction.

Dr. Richter also prepared a paper dealing with the interpretation of the seismograms written by the Benioff instruments, to be presented at the meetings of the International Union of Geodesy and Geophysics at Washington. The paper, intended mainly as an aid to seismologists in other parts of the world using these seismographs, sets forth the interesting fact that very frequently these instruments give excellent records of shocks that are well recorded elsewhere only at stations comparatively near the origins; this is especially true for earthquakes in Japan, South America, and near the Samoan Islands. These distant but very clear records at Pasadena are often very valuable not only for our own study of deep shocks in those regions but also to the workers compiling the International Seismological Summary.

General seismology and geophysics. Dr. Gutenberg and Dr. Richter continued the investigation of deep-focus earthquakes and prepared a paper now being published in the *Bulletin of the Geological Society of America*. It is shown in this paper that the difference in the location of the zones of occurrence of intermediate and of deep-focus earth-

quakes is approximately as large as between shallow and intermediate shocks. The distance between zones of intermediate and of deep earthquakes is in the neighborhood of 300 km., with slight variations in various regions. All intermediate shocks investigated thus far are located on Tertiary structures, and all very deep shocks investigated thus far without exception are around the Pacific area, inland from the intermediate shocks. The investigation of SKS, the wave which travels transversely at the beginning and in the mantle and passes through the core, led Gutenberg to the conclusion that focal points are not unlikely for this wave. The observations indicate that there are strong amplitudes at a distance of about 75° from the origin, and this indicates such a focal point. The results available from deep-focus earthquakes were used by Gutenberg and Richter to improve the travel-time curves of all phases. Additional observations on core waves led to an improved velocity-depth function for the waves through the core, indicating that at a depth of about 5000 km. the velocity of the waves increases by about 10 per cent. It has not been decided whether this increase is sudden or gradual over a relatively small depth interval. The latter seems more probable from the observed amplitudes. The agreement between the revised travel times for a large number of phases and those found recently by Jeffreys is very good, and in general the difference does not exceed 2 seconds for the P waves.

The seismograms of local shocks from intermediate foci in South America recorded at the Carnegie station at Huancaayo furnished another confirmation of results found previously in normal shocks: that at a depth of about 80 km. the elastic constants in the earth seem to decrease slightly, indicating possibly a transition from crystalline material above that level to noncrystalline mate-

rial below. These results are to be presented at the meeting of the Geological Society of America in Berkeley in August 1939.

Gutenberg prepared and delivered an address at the Golden Gate International Exposition on the structure of the floor of the Pacific Ocean as indicated by earthquake waves.

The investigation of the records obtained by two Benioff microbarographs was continued by Benioff and Gutenberg. The use of two instruments about 400 feet apart permits discrimination between true sound waves through the air and changes in pressure produced by irregularities in air currents, as the former waves are recorded simultaneously by the two instruments, whereas changes due to wind and other currents in the air record at different times with different wave forms at the two instruments. Regular sinusoidal waves having a period of a very few seconds and produced by sound (pressure waves) at an unknown source by gunfire, and by other artificial causes, have been recorded and studied. Occasionally waves with a period of less than 1 second have been recorded; these occur in all instances simultaneously with unusually high surf along the coast and are probably sound waves produced by the surf. Occasionally waves with periods between a large fraction of a minute and several minutes are recorded simultaneously on both microbarographs. The effect of wind has been studied. It was found that during a very strong storm and on other windy days the Benioff strain seismograph also records irregular changes in rock strain at the Laboratory, and these cease exactly at the time the storm ends. Corresponding movements were not observed on the records of the pendulum seismometers. The outstanding motion recorded by the microbarograph is due to the circulation of air caused by convection currents produced by the heating

of the ground during a clear day. This movement is very small during the winter and occurs then, if at all, during two or three hours in the middle of the day, whereas in the summer months it begins usually after sunrise and ends at sunset.

New instrument design and construction. The experimental vertical-component moving conductor transducer type electromagnetic pendulum seismometer mentioned in a previous report has been further developed by Dr. Benioff and is now available as a production model. In its present form, the instrument is fully enclosed in an aluminum alloy housing and has been provided with a clamping mechanism for use during transportation. Constraining members have been added to the spring system to prevent transverse vibrations of the springs.

A horizontal-component seismometer similar to the vertical instrument described above has been completed. Its inertia reactor and transducer are identical with those of the vertical instrument. The reactor is suspended with its axis vertical by means of crossed cardon hinges having sufficient stiffness to provide a pendulum period of about 1.2 seconds. The period is adjustable between the approximate limits 0.75 second and 2.0 seconds by means of a leveling screw which tilts the axis of the instrument and thus brings into action positive or negative restoring force due to gravity. The instrument is completely enclosed in an aluminum alloy case.

A measuring machine for film seismograms, described in a previous report, has been completed. The instrument employs a binocular microscope mounted on a double slide micrometer carriage. The micrometer screw in the time direction is calibrated directly in seconds and tenths of a second and can be estimated to 0.01 second. The other screw measures amplitudes and is calibrated in

millimeters. The micrometer structure is mounted on wheels and can thus be quickly rolled to any desired point along the film, where it can be clamped for measurement. A fluorescent lamp 36 inches long is used for illumination.

A projector type measuring device has also been completed for use with film seismograms. In this instrument an eightfold enlarged image of a portion of the film is projected on a ground glass by means of a high grade photographic objective and conventional projection system. The enlarged image, as seen on the ground glass, provides a time scale of 120 mm. per minute, which is twice that of our standard paper seismograms, and a line spacing of 1 cm., four times that of paper seismograms.

A new type galvanometer for use in seismographic recorders has been designed and built in collaboration with Mr. F. E. Lehner of the Laboratory staff. In this instrument the suspensions pass through holes in the circular glass mirror and are soldered directly to the ends of the coil which is wound around the periphery of the mirror. The absence of extraneous parts in the moving system has reduced the moment of inertia, and consequently the sensitivity is some two and one half times that of previously available instruments having the same period (0.25 sec.)

Measurements have been started for determining whether the two surfaces of the Mammoth Fracture, near the east base of the upfaulted Sierra Nevada block, are moving relatively to each other. For this purpose pairs of stainless steel inserts have been placed at opposite points in four locations along the feature. Test bars of steel have been constructed with lengths somewhat less than the actual distance between inserts and the difference is measured with a micrometer caliper. Measurements are accurate to approximately 0.001 inch or approximately 1/50,000. Thus a move-

ment of 0.1 inch per century should be detectable in a few years' time.

Seismic sound waves produced by the movement of the ground in the vicinity of the epicenter of an earthquake which has been located approximately 700 km. south of the Laboratory have been well

recorded on the electromagnetic micro-barograph. The waves were recorded for approximately 15 minutes, indicating that the waves first received were generated at a point 550 km. from Pasadena and the last received waves at a point 850 km. from Pasadena.

F. A. PERRET, Martinique, British West Indies. *Earthquake problems, Montserrat, British West Indies.*

The Carnegie Corporation of New York has provided funds for these investigations, which during the past year have included the following: Studies have been continued at Dominica, where the same order of seismo-volcanic manifestations as had been occurring at Montserrat (forming the subject matter of the book now issuing) showed certain important differences, in their migration to this island, which merited comparative study.

The Montserrat report indicated some new modes of subvolcanic functioning, and a seemingly not heretofore appreciated method of surface growth, in the so-called *piton* formation. A number of excursions were made to the outstanding "Pitons of Carbet" in Martinique for photographing and specimen taking, and the study was extended to the celebrated Pitons on the island of St. Lucia, where a preliminary investigation was also made of the Soufrière region for confirmation of the writer's opinion that this was located in a former primary crater—which was shown most effectively by the presence of thousands of volcanic bread-crust bombs. This region

merits further study of both Pitons and Soufrière, and the writer proposes to return before the end of the present year for further study. Needless to state, a rich photographic documentation is resulting from all this work in the field.

The Laboratory museum at St. Pierre, together with the writer's private laboratory, have permitted some experimentation designed to verify the new hypothesis presented in the Montserrat report as to gas-liquid differentiation in horizontal subterranean conduits. These studies, with others regarding the modus of out-throw of clastic materials from the crater, and still others as to subsurface geyser functioning, are believed to be of importance in furthering our accurate perception of the processes of volcanism.

The work includes the constant adding to collections of volcanic materials—the museum's series of bombs being quite unique, from those of a gram or two up to some of 600 kg.

The Montserrat book has been completed (*The volcano-seismic crisis at Montserrat, 1933-1937*, Carnegie Institution of Washington Publication No. 512).

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